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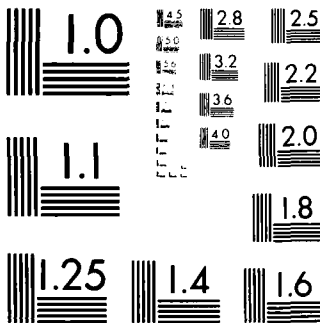
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European Science Notes

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May 1985
Volume 39
Number 5

Behavioral Sciences

New Information Technologies and Technical Education:

The Experience of Sweden, France, and West Germany Richard E. Snow 179

Three countries pool their experiments and problems in adapting their educational systems to advances in computer technology. General policy issues for future planning are thereby sharpened.

The Experimental Psychology Society: Notes on Auditory

Perception, Working Memory, and Circadian Rhythm Richard E. Snow 183

The most recent meeting of the society included new findings on multiple sources of information in auditory intensity judgments, periodicity detection in audition, the similarity of auditory nonverbal memory to verbal working memory, and unique circadian rhythms associated with performance where working memory load is high.

Biological Sciences

Hydrogels Form New Basis for Drug Delivery in

Systems Being Developed by Scottish Firm Thomas C. Rozzell 187

Polysystems, Ltd. has been set up in Scotland to manufacture and license hydrogels for drug delivery. This article describes the Scottish research, discusses the characteristics and uses of hydrogels, and examines how hydrogels may benefit military medicine.

Computer Sciences

Algebra, Transformation Theory, and Knowledge Engineering

Replace Alchemy at Munich's Technical University Paul Roman 190

The Institute for Information Science at Munich's Technical University is trying to organize software development and computer programming as a sequence of steps of rational reasoning. The institute's director, Professor F.L. Bauer, says that right now the programmer's day is "full of alchemy," even though the current status of logic programming and knowledge engineering offers highly powerful, rational, and cost-effective approaches.

Alvey Program Funds MMI Projects Larry E. Shaffer 192

The UK's Alvey Directorate has funded the following projects dealing with the man-machine interface (MMI): voice-operated database, intonation in computer-generated dialogue, MMI in command control, interactive computer systems, adaptive intelligent dialogues, object identification from two-dimensional images, and speech interfacing and phonetic algorithms.

Material Sciences

- Luleå University--A Hot Spot for Materials
Research in the Frozen North Kenneth D. Challenger 193

The Materials Engineering Department of Sweden's Luleå University of Technology is at the forefront of research in certain areas of materials science. This article highlights work on structural ceramics, dual phase steels, hot isostatic pressing maps, welding maps, laser hardening of steel surfaces, and the stability of precipitates in microalloyed steel.

Mechanics

- Fluid Dynamics at the von Karman Institute Charles J. Holland 199

The von Karman Institute (VKI) in Brussels, Belgium, is an international center for education and research in fluid dynamics. This article describes the VKI's education programs and its research on hypersonic, supersonic, and high subsonic phenomena.

- LEBUs at Saltsjöbaden Patrick Leehey 201

Large eddy breakup devices (LEBUs) were a principal topic for discussion at EUROMECH 181, held in Saltsjöbaden, Sweden, from 29 through 31 August 1984. Thin ribbons placed in tandem across the outer portion of a turbulent boundary layer provide marked reduction in frictional coefficient, but a total drag reduction of at most 5 percent experimentally to date.

- 1984 Ship-Hydrodynamics Meetings Choung M. Lee 206

Two important technical meetings on ship hydrodynamics were held in September 1984. This article covers highlights of the 15th Symposium on Naval Hydrodynamics and the 17th International Towing Tank Conference.

Physics

- Lasers and Laser Accelerators at Rutherford
Appleton Laboratories, UK Paul Roman 209

Advanced methods for generating front-line laser systems and ultra-high-energy beams of charged particles are the focus of several projects of the Central Laser Facility at the UK's Rutherford Appleton Laboratories. This article surveys laser development and research and examines work on beat-wave laser accelerators.

- Laser Research at Imperial College, London Paul Roman 211

Laser research in the optical section of Imperial College's Physics Department focuses on the following areas: narrow bandwidth tunable VUV lasers, Brillouin scattering and applications, mode-locked ring CW dye lasers, color-center lasers, and mode-locked semiconductor lasers.

- New Directions at an Old Department: Gyrotron and
Fiber Sensor Research at King's College Paul Roman 217

The Electronic and Electrical Engineering Department of King's College, London, is rapidly changing its profile. Research in the forefront of gyrotron theory as well as a new research group for fiber sensors testify to the department's enthusiasm, flexibility, and talent.

Science Policy

- R&D Support Increasing in OECD Countries Larry E. Shaffer 220

The Organization for Economic Cooperation and Development (OECD) has published a report that focuses on trends in the funding and structure of national R&D efforts in the 1970s and examines prospects for the 1980s. This article discusses some of the report's findings in three areas: national R&D trends in OECD countries, government support for R&D, and industrial R&D.

- Swedish Defense Policy and R&D Activity CAPT L. Laddie Coburn, USN 221

Sweden is the leading industrial, economic, scientific, and military power in Scandinavia. This article surveys Sweden's defense organization and examines the work of the National Defence Research Institute and the Defence Materiel Administration.

Space Sciences

- ESA's Future Program in Earth Observations Norman F. Ness 226

The European Space Agency has published a report, *Looking Down, Looking Forward*, which discusses future work in Earth observation. This article discusses the four key areas for missions identified by the report: meteorological research, ocean/ice observations, land-surface monitoring, and solid-Earth geophysics.

News and Notes

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Imperial College Patrick Leehey 229
- UK Sets Up Space Center, Gives £7M to
European Projects Larry E. Shaffer 230
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ESN Invites Letters to the Editor

ESN publishes selected letters related to developments and policy in science and technology in Europe and the Middle East or to interactions between the US and Europe and the Middle East in science and technology.

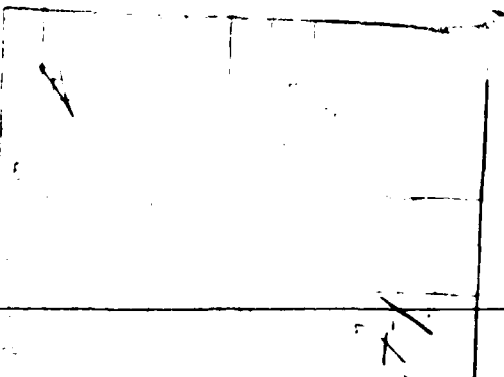
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Behavioral Sciences

NEW INFORMATION TECHNOLOGIES AND TECHNICAL EDUCATION: THE EXPERIENCE OF SWEDEN, FRANCE, AND WEST GERMANY

by Richard E. Snow. Dr. Snow is the Liaison Scientist for Psychology in Europe and the Middle East for the Office of Naval Research's London Branch Office. He is on leave until September 1984 from Stanford University, where he is Professor of Education and Psychology.

The advance of science and technology is critical for national economic health. New developments in this advance have major impact on labor markets through their demands for new kinds of knowledge and skill from trained personnel. But the educational systems of most Western countries are relatively autonomous, and thus slow to respond to such demands for change. How are these educational systems responding to the rapid development of new information technologies (NIT) in recent years? How can they be better adapted to meet the demands of this development?

These questions motivated a survey of the experiences of three major industrial countries in Europe that face this problem. The survey was conducted for the Organization for Strategic Labor Market Research in The Hague, The Netherlands. A report in English is now available, authored by Jallade (1984), based on the detailed country reports of Grünwald (1984) for West Germany, Bertrand (1984) for France, and Myrberg (1984) for Sweden.

Sweden

The Swedish educational system is based on the comprehensive school at the upper secondary level that integrates vocational, technical, and general educational programs. Up to 1975, however, the main providers of NIT competence were industrially based training programs. Although an increasing number of students are choosing vocational or technical programs in secondary school (74 percent in 1983), only a few of the 50 specializations available are NIT-related. The NIT-related programs are unable to keep up with the demand for trained persons. It is estimated that about 1 percent of the labor force (of about 4 million) can be considered NIT specialists and 7 percent can be called

qualified users, in jobs where NIT competence is commonly required. About 30 percent of all jobs are affected somehow by NIT.

Direct recruitment of NIT specialists from the educational system has actually decreased in recent years to about 33 percent of total recruitment. About 60 percent of the NIT specialists come from other occupations through adult retraining programs; these are the "double-qualification" specialists. It is unlikely that the secondary school programs can fully qualify persons as NIT specialists, but they must provide a level of education that prepares students for industrially based further training in specialties at the technician level and for higher education at the level of electronics and computer engineering. However, the output of engineers leveled off in Sweden after 1975 due to fewer students taking science in secondary school. The increasing demand for engineers and the high salaries available have so far not increased student interest in science, which is considered by many of them too difficult a subject. There is concern also that the level of science and mathematics education available in secondary schools is insufficient to provide many strong candidates for advanced NIT-related programs.

Several adaptive measures have been taken. In 1975, courses in programming and computer hardware first appeared in secondary schools. Engineering production planning and economics were also introduced. Computer science was introduced as a secondary school option in 1980. Computer literacy courses became a mandatory part of social science and science education in the compulsory curriculum in 1982. A minimum of 2 hours per week must be devoted to NIT-related instruction as of 1983. About 66 percent of compulsory secondary schools in 1983-84 had an average of 7.3 computers each. BASIC is the most common programming language being taught. Teacher training in NIT is now top priority. About 5000 teachers per year will receive basic instruction in NIT. At least one teacher per school will have advanced training so that every school can have at least one NIT specialist.

France

In France, there are several routes through the public education system that lead to one of three levels of technical competence: the *qualified worker*, requiring 10 or 11 years of education, and sometimes an apprenticeship; the *technician*, requiring completion of the secondary education technical stream;

and the *diplôme de technicien*, requiring 2 years of post-secondary study in short-cycle higher educational institutions. There is also now a network of 121 centers for young adult vocational training; these courses aim increasingly at the technician and higher technician level. And special laws enacted in 1972 and 1981 provided for special training programs in industry. However, only a small portion of these opportunities are concerned with NIT specialties.

NIT personnel are divided into two categories in France: specialists and professional users. Specialists are further divided into *informaticiens* (essentially software specialists) and *électroniciens* (essentially hardware specialists). Estimates vary, but one count suggests there were 200,000 *informaticiens* in 1983. Counting all specialists and professional users, there were 800,000. This is 3.6 percent of the labor force. In another, nonprofessional user category, it is expected that 3 million clerical jobs, for example, will be affected by NIT. It is also expected that the line between specialists and nonprofessional users will shift in the coming years, as specialists become more highly specialized and previously complex procedures are made simpler for nonprofessional users.

France is attempting to increase the output of graduates in existing educational programs and also to create new degree programs. In 1982, a 3-year plan was instituted to increase the flow of NIT-trained engineers by 50 percent and higher technicians by 15 percent. There was a slow start, but numbers are now increasing at these higher educational levels. Increases at the lower levels of technician and qualified user, however, are still very slow and small. New programs include two degree programs in electronics and three in informatics. Adult retraining is also being pushed. Beyond these educational programs, two others deserve special note. In one, NIT consulting firms, some of which are the biggest in Europe, are devoting about 3.5 percent of total turnover to their own personnel training. These are the major producers of double-qualification specialists. In the other program, starting in 1983, university graduates in NIT-related fields can fulfill their national service requirement by volunteer teaching of NIT skills to young unemployed persons. The program first gives special training to the trainers; they then teach in one of 10 training centers for periods of 3 to 9 months. In September 1983, there were 10,000 unemployed persons being trained in NIT by 400 trainers in this program.

Most observers doubt that serious NIT training can take place without completed secondary education as a prerequisite. Thus, special NIT programs should focus on higher levels; most traditional training is only at the qualified worker level. The proper duration and content of NIT-training programs is also a controversial issue. Labor market demand presses the creation of short operational courses aimed at providing immediately marketable skills. The risk is that skills so trained become obsolete as NIT continues to develop. Placing practical training in industry and theory in the public educational system is not a solution; in NIT, theory and practice are closely and dynamically interconnected. There is also not consensus on what the fundamentals of NIT are that should be taught. Alternative school-based and work-based training is thought to be a partial solution, at least.

NIT-related learning for general education is also controversial. Resistance to change is strong in this sector in France, given that mass retraining of teachers and redesign of curricula would be required. Since 1982, 200 new positions per year for NIT teachers have been created in the public schools. Also, teachers from math, physics, and mechanics are being retrained. Part-time teachers from industry are also being recruited; about 30 percent of teaching time in NIT courses will be filled with such teachers. Plans call for 100,000 microcomputers to be operational in schools by 1988. There were between 12,000 and 20,000 in mid-1984. But 600,000 would be needed to ensure that each student has 20 minutes of daily contact with a microcomputer.

Other serious problems remain. There is lack of student interest in technical education at upper secondary levels; students continue to prefer more general educational programs. The commissions responsible for defining curriculum content have been slow moving and bound too much to traditional disciplines. Teachers' lobbies have resisted change, while fighting to get the best of NIT, instead of looking toward adapting the school curriculum to NIT. Finally, the French system is highly centralized; curriculum reform traditionally is top-down and therefore slow to be implemented. This sort of system makes local experiments and initiative largely impossible.

West Germany

In the West German view, NIT is not likely by itself to determine the content of jobs and a new structure of

skills. The spread of NIT in industry is left to private firms. Thus, forecasts of NIT-related labor-force needs are of little value; they should not be targets for education and training policy. Opinion is divided as to the implications of NIT for education. Some emphasize the importance for future NIT of developing abstract, theoretical thinking abilities, a job best done by basic general education, not vocational or technical training programs. Others urge that NIT knowledge development cannot be divorced from training closely linked to industry operations.

The estimates of labor-force effects of NIT that have been made indicate that 3 percent of all jobs include a major NIT component now. The influence of NIT will soon be felt in at least 7 percent of all jobs. Over the next 10 to 15 years, more than 35 percent of all jobs will be affected. Another study suggests that 12 percent of jobs requiring formal vocational training will be affected by NIT, and that about 33 percent of the content of these training programs will need to be revised.

Germany already has a dual system that combines vocational school training with work experience and firm-based training. But the system does not work as well in practice as its plan on paper. The rapid change accompanying NIT forces firm-based training toward narrow over-specialized skills. Many firms are too small and too specialized for the dual system, so training centers common to groups of firms may need to be established. Vocational schools are now devoting a first basic year to general training to avoid premature specialization in one occupation. But in the NIT domain, firm-based training is adapting more rapidly than is vocational school training, so the gap in the dual system is widening.

As in other countries, firm-based training has up to now been the main provider of NIT skills, bridging between labor market demands and the lag of the educational system. There is now also such specialist training and retraining of adults, sponsored by chambers of commerce, professional associations, and some technical schools. The higher technical schools (*Fachhochschulen*) are not yet involved but plans exist to open this avenue. The popular universities (*Universitäten*) are heavily involved.

It is critically important that the higher technical schools implement plans for advanced NIT training. It is estimated that the number of data processing specialist jobs (131,000 in 1980) is increasing by 8 percent per year. But

the educational authorities in West Germany are reluctant to push new training programs for NIT specialists; they are cautious about over-reacting to the estimates, they believe double-qualification persons are more useful than pure specialists, and they place more faith in labor-market adjustments than in state interventions.

The secondary schools are still far behind in meeting the needs for teaching informatics as a subject on its own, using NIT in the teaching of other subjects, and introducing NIT into such subjects as ergonomics. Equipment available to public schools is still limited and varies significantly across the several German states (*Länder*). A series of pilot experiments in NIT for vocational training is planned for the 1984-87 period.

Overview of Policy Issues

This section summarizes some general policy issues, using material provided in the basic reports as well as that indicated in the abstracts above. The issues can be enumerated as follows:

1. Technical and vocational educational systems have been generally unable to keep up with the demand for NIT skills and knowledge, and should not be expected to do so, at least in the next decade or so. In-company and on-the-job training, and recurrent education for working adults have filled part of the gap between soaring demand and lagging supply and should continue to do so. In the long view, this condition may be advantageous. Many NIT concepts have not yet reached consolidation or consensus. Out-of-school training programs can respond quickly to changes in demand. The inertia of the public school system allows time to sort out and elaborate a more fundamental doctrine for NIT training and its long-term consequences beyond immediate labor market needs.

2. It is difficult if not impossible at present to reach a comprehensive statistical picture of NIT-related occupations. Adequate data are scarce and difficult to come by. Job and level classifications differ across countries. There is widespread scepticism about the feasibility and usefulness of making detailed forecasts for the various categories of NIT personnel. Nonetheless, a generally applicable classification of NIT personnel should be helpful for planning purposes and for thinking about alternative kinds of education and training programs. Table 1 reproduces the classification system proposed by Jallade (1984).

Table 1

NIT Occupations and Modes of Training (from Jallade, 1984)

1- SPECIALISTS

High level specialists	designers of systems	} University training in NIT plus applied out of school (in company) training in one specific field (agriculture, health, industry, etc.)
	designers of applications	
	NIT teachers	University training in NIT
Middle level specialists	'short cycle' higher education plus in-company training	
Maintenance and servicing personnel	Technical vocational education at upper-secondary level plus in-company training	

2- PROFESSIONAL APPLIERS

Industry	} University training in one field plus NIT training through recurrent education or in-company training
Office work	

3- NIT USERS ON THE JOB

Industry	Technical education, alternance training and in-company training
Services	Technical education, alternance training and recurrent education

4- NIT USERS OFF THE JOB

NIT training aimed at computers' literacy in compulsory and post compulsory general education and in adult education

3. At present, the number of *high-level specialists* is small and, contrary to popular belief, future needs are not likely to be large. The exception to this is the substantial need for specialist teachers at other levels in the training system. *Professional appliers* are in large numbers now and will be in much larger numbers in the future. This is the present category for double-qualification persons. As double-qualification needs increase, these will have important implications for change in the nature of training in the qualification discipline that has not been traditionally NIT-related. For the two NIT user categories shown in Table 1, a comprehensive training strategy involving the entire educational system is needed to deal with the very large needs and numbers involved.

4. NIT training more easily "invades" the upper degrees and levels of education than the lower. It also requires a higher level of education for entry than many traditional training areas. There is an economic side to

this, since high NIT skill and long formal schooling become naturally correlated, and both draw higher wages in the market place. A sociological side is also apparent; the more prestigious and socially selective levels of education are the first to incorporate fashionable kinds of training. There is also a psychological aspect; NIT training may indeed require a higher level or more specialized kinds of abstract reasoning and logical thinking abilities than many traditional occupations. Technology seems to increase distinctions; thus, NIT training may drive a wedge between the "haves" and the "have nots," increasing apparent individual and group differences. The educational strategy needs to be carefully geared to counter this trend in the population as a whole.

5. There appears to be a minimum level of general education required for NIT training, which of course varies with the level and kind of specialization targeted. NIT training is reinforcing existing trends in all three countries toward upgrading the educational

attainments of the work force. There also appears to be a trend toward more general rather than more specialized NIT training. Although in Sweden and France there is clear separation between school-based and firm-based training, and thus between general and specific training, in Germany the dual system is well established and appears to have distinct advantages in defining and correlating the important features of each. The incorporation of NIT into general education may also contribute a base of transferable intellectual skills that helps break down traditional disciplinary divisions. NIT training may then become part of the minimum level of general education provided to everyone. On the other hand, NIT requires upgrading of secondary science and mathematics streams at a time when students already perceive those streams to be too demanding and thus too risky. A key problem is to adapt science, mathematics, and NIT secondary education to ensure adequate quality and quantity of students for higher education in this realm.

6. For the training of double-qualification persons, there is a tension between the view that broadening existing curricula to incorporate NIT courses is the best route and the view that new specialized departments and even institutions are needed. The first view seeks to avoid isolation of NIT and to encourage communication and dissemination of NIT as an instrument throughout the economy. The second emphasizes the need for new skill and knowledge development and consolidation. The real issue, of course, may be when and where to do which, given that both are ultimately needed. The Swedish and German reports tend to emphasize the first view; the French report emphasizes the second.

7. The contribution of adult and recurrent education to NIT training is vitally important. Short courses will always be needed to fill training gaps even if NIT training is also given at all levels in the school system. Also, the training of adults will always require a network of out-of-school programs.

8. There are at least three major implementation problems in adapting education to NIT. Trained teachers are generally in short supply everywhere. The issue is not just one of training but also of overcoming rigidities in teacher organizations and civil service pay scales that provide negative incentives. Equipment and software are limited and of variable quality. In some countries, notably Sweden, educational authorities are playing an

increasing role in specifying standards to be met by educational computers and software. The student-flow problem in NIT, related science and mathematics, and other traditional fields suggests that major curriculum revisions are needed and that student-flow planning and counseling need careful, continuing attention.

9. Innovation and experiment tend to occur more easily in decentralized educational systems. Pilot experiments are an extremely important part of the adaptation process. Consultative commissions are also an essential link between the needs and interests of education, industry, and government concerning NIT. Efforts to improve the functioning of innovation and consultation mechanisms should be included in any strategy aimed at adapting technical education to NIT.

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THE EXPERIMENTAL PSYCHOLOGY SOCIETY: NOTES ON AUDITORY PERCEPTION, WORKING MEMORY, AND CIRCADIAN RHYTHM

by Richard F. Crow.

The Experimental Psychology Society is a small, unique group, centered in Britain but independent of the British Psychological Society. The Experimental Psychology Society's membership includes about 75 British-based researchers, with about 45 more scattered throughout Western Europe, the Middle East, North America, and Australia; among these are 14 in Canada and 14 in the US. The society

publishes the quarterly *Journal of Experimental Psychology* in two sections (*Journal of Experimental Psychology* and *Journal of Experimental Psychology: Applied*). It also holds three to four scientific meetings per year, sometimes jointly with other groups such as the British Physiological Society or the Dutch or the Italian experimental psychologists. The current president is Dr. Alan Baddeley, director of the Medical Research Council-Applied Psychology Unit, Cambridge; correspondence regarding the society and its future meetings should be addressed to the Hon. Secretary, Dr. R.G.M. Morris, Psychological Laboratory, University of St. Andrews, St. Andrews, Fife, KY16 9UN.

The society's most recent meeting, held at the University of London on 3 and 4 January 1985, provides a good example of the quality of work it fosters. Table 1 abstracts the program, to give a sense of the range of topics of interest to members. The present article focuses on new findings discussed at the meeting under two headings: auditory perception and working memory, and working memory in relation to circadian rhythmicity in performance.

Auditory Perception and Working Memory

The findings presented by Carlyon, Patterson, and Edworthy suggest some important lines for new research. The case studies reported by Sloboda and by Campbell add interesting implications.

According to Carlyon, the smallest increase in the intensity of a faint tone that humans can detect is about 2 dB, and this decreases gradually with increasing level. Such findings represent a systematic deviation from Weber's law, for tone levels up to 95 dB SPL. But physiological evidence suggests that the firing rates of most auditory nerve fibers tuned to a signal frequency be-turated at about 60 dB SPL. The apparent contradiction can be resolved by the hypothesis that humans are able to use alternative sources of intensity information, such as a second, small population of nerve fibers specialized with low thresholds to convey intensity at high levels. Carlyon thus conducted several experiments to measure intensity difference limens for brief signals when additional sources of information are removed. Signal frequencies greater than 5 kHz eliminate information arising from the regularity of nerve impulses. Noise masking eliminates information from fibers tuned away from the signal frequency. When, and only when, these sources of information are both blocked, the difference limen is maximized at

14 dB at intermediate tone levels, where neither population of fibers tuned to the signal frequency can code intensity. The results support the hypothesis that humans use multiple sources of information in intensity judgment and suggest a new model of departures from Weber's Law and of breakdown in auditory recognition at high intensity levels.

Patterson presented a new model of periodicity detection, in which a spiral processing mechanism is assumed in the initial stages of the auditory system to extract periodicity information from the stream of neural impulses. Peripheral processing of periodic sounds is environmentally significant for animals and for humans; the detection mechanism must thus be passive and fast. The spiral hypothesis fits this requirement and also has constraints that fit the fact that some combinations of musical notes sound better together than others, i.e., our harmonic scales. The log spiral (base 2) provides a good model and a convenient conversion from a temporal to a spatial pattern for the stream of neural pulses.

Edworthy reported two experiments indicating that mechanisms previously shown to be involved in processing and storage of verbal material in working memory are similarly involved when the material is auditory nonverbal. The work relates to Baddeley's (1983) model of working memory which posits several subsystems, one of which is an articulatory loop that serves primarily as an input store in speech perception but which can also be used by a person as an active memory store by means of subvocal rehearsal; there is also the hypothesis that a separate "inner ear" mechanism is involved in auditory imagery. The first Edworthy experiment investigated recognition memory for melodic sequences using the Baddeley paradigm; articulatory suppression, homophone judgments, or visual symbol matching were the alternative secondary tasks. The second experiment used pitch discrimination as the primary task, with the same secondary tasks. Recognition performance was disrupted by both articulatory suppression and homophone judgment, implying that both the articulatory loop and the "inner ear" of working memory were involved. Pitch discrimination was disrupted only by simultaneous homophone judgment, implying that the "inner ear" but not the articulatory loop was involved. In short, the Baddeley model seems to fit auditory nonverbal processing as well as auditory verbal processing.

Campbell reported the case of a university student with normal speech

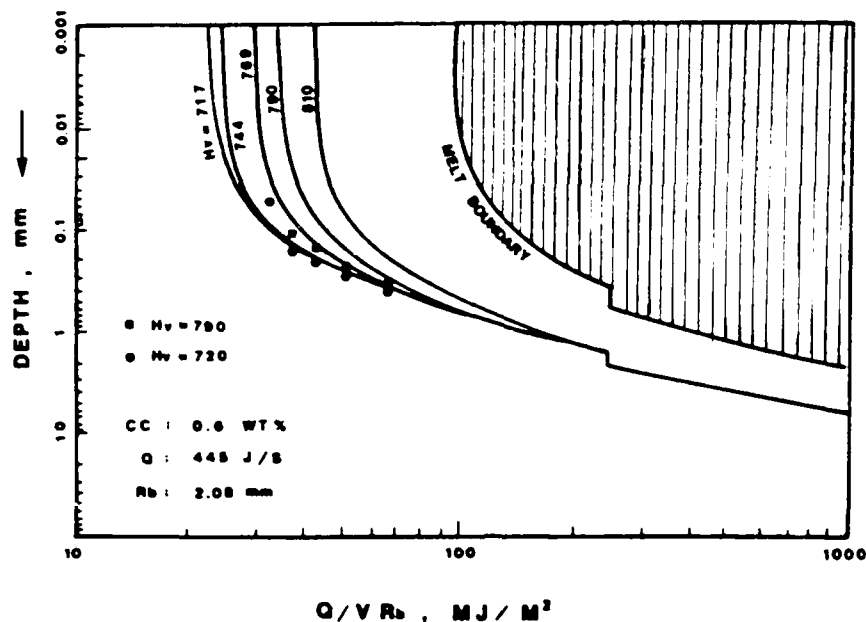


Figure 6. A laser processing diagram for 0.6 wt percent plain carbon steel with grain size 15 μm (from Li, 1984).

order to avoid melting and to achieve the highest surface hardness and the deepest penetration of the surface treatment, the energy input/unit area should not exceed about 100 MJ/m^2 .

Though it has not yet been done, these diagrams could be extended to include glazing and surface alloying (where melting does occur). The significance of this work is that it illustrates that with careful attention to the fundamental principles of thermodynamics and kinetics it is possible to accurately model a very complex process. These models are very useful in finding the optimum chemical composition and the laser processing conditions to achieve the desired surface properties (hardness and residual stress).

Stability of Precipitates in Microalloyed Steel

Easterling has many research projects that are relevant to the development of steels with improved properties, especially weldability. Jan Strid (1984) has used transmission electron microscope-based and scanning transmission electron microscope-based microanalyses to study particle size dispersions and compositions of carbides and nitrides in several different Ti- and Nb-microalloyed steels. Various thermal treatments were used to determine the effects of precipitate size and composition on

their stability. Al, V, Ti, and Nb--when present in small amounts--react to form nitrides and carbides which promote grain size refinement in steel by producing grain size pinning dispersions of precipitates. The thermal stability of these precipitates will affect both the recrystallized grain size following hot working and the grain size in a weld HAZ subsequent to welding. Since it is desirable to keep the grain size as fine as possible in order to increase strength and resistance to brittle fracture, the thermal stability of these particles and the mechanisms by which they coarsen and dissolve must be known. TiN is the most stable of the precipitates and thus produces the most weldable currently available microalloyed steel. Therefore, these steels have been the subject of a great deal of interest. When several of these alloying elements are present, there are synergistic effects that are not very well characterized.

Strid's research was aimed at understanding the behavior of these precipitates in ternary alloys (for example Ti-V-steel). His main conclusions include:

1. The addition of extra nitride formers to a Ti microalloyed steel such as V, Nb, or Al results in an increase in the precipitate size. Al has the

Laser Hardening of Steel Surface

The development and application of lasers for materials processes such as cutting, welding, drilling, and surface treatment has reached the stage of commercialization. Surface transformation hardening of steels represents an excellent method in which the surface of a steel component can be selectively treated without affecting the bulk of the material. Lasers are used to heat the surface without melting (transformation hardening and annealing); to melt the surface (glazing, alloying, cladding, grain refinement); or to vaporize the surface, which can induce shock hardening.

Wenbin Li, under Easterling's supervision, has developed the differential equations for heat flow which define the temperature distribution at the surface and in the interior of a material which is scanned with a laser beam. These equations are combined with equations for martensite formation to predict the microstructure and hardness profiles resulting from the laser hardening.

By increasing the hardness of a surface, the wear resistance is usually increased. However, often the residual stresses produced in the surface by the hardening treatment also improves the fatigue life. Li has developed a simple model for residual stresses by coupling temperature, phase transformations, and stresses. Figure 4 illustrates the principles of this coupling. The coupling paths 1 through 6 express the influence of one parameter on the other. For example, path 1 describes the influence of the thermal cycle on the martensite transformation, while path 2 describes the effect of the volume change which occurs during the formation of martensite on the surface stresses and strains. Figure 5 illustrates the residual stresses, after a specified laser hardening treatment, in steels with different carbon contents. The surface contains the maximum compressive (negative) stresses and these increase with carbon content, but the depth of the residual stress is similar for all three steels. Increasing carbon promotes the formation of a larger volume fraction of martensite which causes an increase in the residual stresses, but since the thermal cycle is the same for all three steels, the residual stresses disappear at the same distance below the surface. This model predicts the correct order of magnitude for the residual stresses and a distribution of the residual stresses which agrees with experimental data.

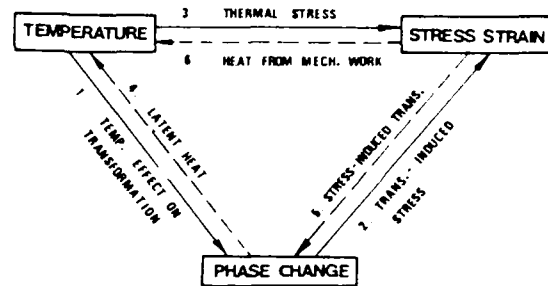


Figure 4. Coupling diagram (from Li, 1984).

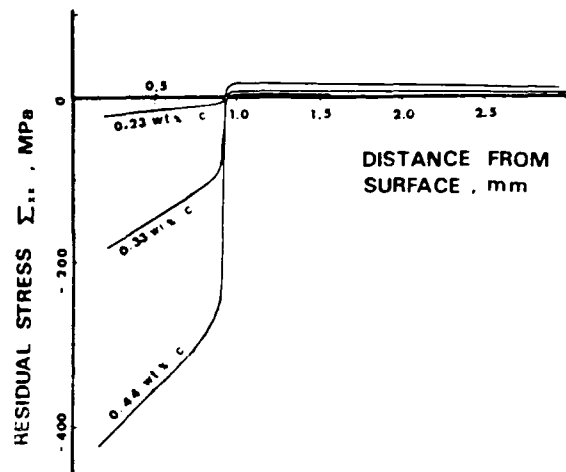


Figure 5. Calculated stress distribution for different carbon contents (from Li, 1984).

Laser-processing diagrams (or maps) have also been developed using an approach similar to that previously described for welding. These diagrams allow one to select the optimum processing parameters (heat input, beam diameter, and beam scanning velocity) that will give a maximum surface hardness without melting. Figure 6 presents a laser processing diagram for a hypoeutectoid plain carbon steel (0.6 percent C). The boundary for melting as a function of energy input/unit area is shown as are the hardness contours (Hv) as a function of distance from the surface for a given energy input. The hardness decreases with distance away from the beam both on the surface and through the thickness. The starting hardness of the steel prior to surface treatment was Hv 720. The diagram indicates that in

for precipitate dissolution and coarsening, grain growth, and martensite transformation to predict the microstructural information shown in Figure 2. The solid lines represent lines of constant austenite grain size (70, 200, and 300 μm). The circled point on the solid 200 line was the calibration point found in the HAZ. The shaded grey region defines the region where the NbC precipitates will dissolve (no dissolution to the left and complete dissolution to the right of the shaded area). The volume fraction martensite is calculated from kinetic equations which describe the transformation of austenite to pearlite, bainite, and, if the cooling rate is fast enough (Δt small enough), martensite. Whether or not martensite forms is a function of Δt , the austenite grain size, and the composition of the austenite (evaluated using the carbon equivalent developed by the International Institute of Welding for assessing cold cracking susceptibility). For example, using Figure 2 it is possible to predict (for these thick plate welding conditions) the austenite grain size (many of the mechanical/fracture properties of the material are a function of the grain size) as a function of heat (energy) input and location in the HAZ (peak temperature). Additionally it is possible to estimate the hardness at the various locations in the HAZ by using Ion's rule of mixture equations and the predicted microstructures, which depend on the cooling time between 200°C and 500°C and the composition. Figure 3 presents a comparison between the predicted and actual hardness profiles and austenite grain sizes as a function of distance from the weld fusion line for a Nb-microalloyed steel GMAW weld. The shaded area again represents the region of NbC dissolution (note the correlation between NbC dissolution and the onset of grain size increase consistent with the concept that the NbC particles inhibit austenite grain growth, once they dissolve grain growth becomes very rapid).

These diagrams provide a means of assessing the effects of welding in terms of the chemical composition, the geometry of the weld, and the welding parameters. The models are semiempirical in that some of them must be calibrated with a single experimental point, but they are based on sound thermodynamic and kinetic principles and, as such, represent a big step forward in understanding and describing the effects of welding on metallic materials. (For further details see Ion, Easterling, and Ashby, 1984.)

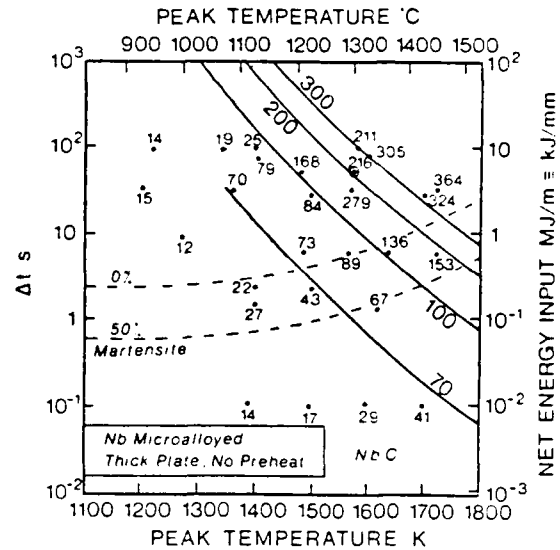


Figure 2. An HAZ diagram for Nb-microalloyed steel; thick plate welding condition, no preheat; experimental data from both bead-on-plate and simulated welds. The full lines are contours of constant austenite grain size, the broken lines show the volume fraction of martensite, and the shaded region shows the extent of dissolution of the carbide particles (from Ion, 1984).

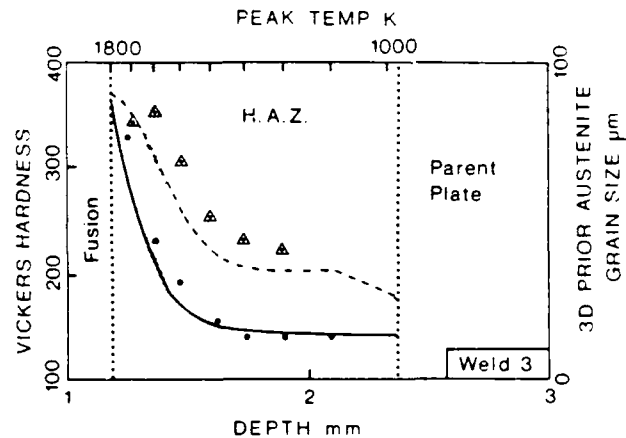


Figure 3. HAZ profile for a GMAW weld on Nb-microalloyed steel. The full line shows the austenite grain size, the broken line shows the hardness, and the shaded region marks the dissolution range of NbC precipitates. Experimental measurements are indicated (from Ion, 1984).

becomes more dense). With the first application of pressure, the particles interact elastically, and then as the pressure increases they deform by plastic deformation. The deformation increases the contact area among the particles, thus reducing the contact force per unit area on the particles. Therefore, eventually the applied pressure will not be sufficient to cause further plastic deformation. At this point the densification process must continue by more time-dependent mechanisms such as power-law creep and diffusion to the void surface. Each of the various densification mechanisms depends on the particle size and the external variables of temperature and pressure. By developing mathematical models based on the controlling physical mechanism (such as grain boundary diffusion, bulk diffusion, surface diffusion, and plastic flow), and plotting them in various ways (fixed pressure with density and temperature as parameters, fixed temperature with density and pressure as parameters, and fixed density with pressure and temperature as parameters), it is possible to identify the mechanism controlling the densification process for a given material as a function of density, pressure, and temperature.

Maps for tool steel, nickel-base superalloys, alumina, and ice have been developed. With these maps it is possible to select the optimum conditions of particle size, temperature, and pressure to produce the most dense product in the shortest possible time.

Welding Maps

Easterling and J.C. Ion have completed a study in which mathematical models for the heat flow in the heat affected zone (HAZ) have been used to develop predictive methods for estimating grain growth, precipitation, and the HAZ hardness which result from the thermal cycle during fusion welding. These maps are developed by using a set of heat flow equations originally developed by D. Rosenthal, but modified by Ion. The Rosenthal equations only describe heat flow in the HAZ. Ion has modified these equations to predict such things as weld penetration and weld geometry, but his equations must be experimentally calibrated to a particular set of welding conditions, because a characterization of the entire welding process would require as many as 28 parameters. The effects of changes in the shielding gas, flux, and convection currents in the weld pool were considered too complex to model; these are taken into consideration in the calibration experi-

ments. These equations, once calibrated, are used to predict the thermal cycle of all regions of the weldment with the assistance of a microcomputer. Figure 1 presents a comparison of the thermal history predicted by these equations with experimental data at a specific location in the HAZ of submerged-arc (SAW) and gas-metal-arc (GMAW) welds.

They then derive expressions (from theoretical principles) for the kinetics of grain growth, precipitate coarsening, and dissolution and the phase transformations in the HAZ during cooling. Using the predicted microstructures and a rule of mixtures, they predict the hardness of each position in the HAZ for a range of energy inputs. Figure 2 presents an HAZ diagram for a thick plate of Nb-microalloyed steel.

Moving from high to low temperature is essentially the same as traversing away from the fusion line into the HAZ. The peak temperatures and Δt (the cooling time between 800°C and 500°C, the critical temperature range for the transformation of austenite) are determined from the heat flow equations used to produce Figure 1. This information is then used in the kinetic equations

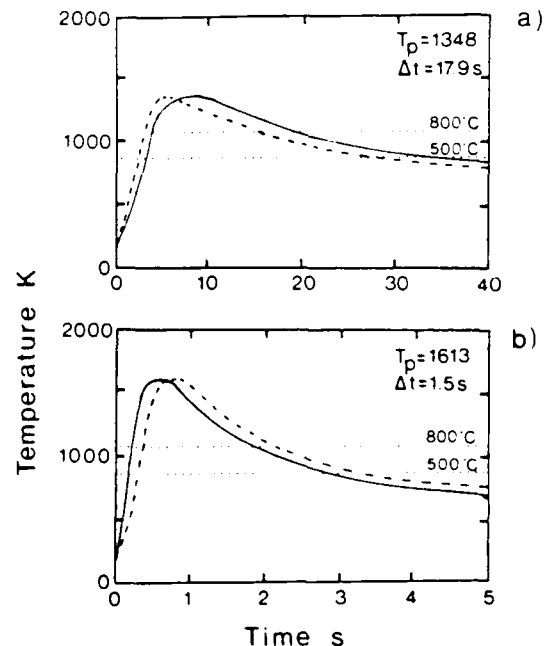


Figure 1. Comparison of thermal cycles measured from (a) SAW weld and (b) GMAW weld (full lines) together with the predictions (broken lines). (From Ion, 1984.)

The department is exceptionally well equipped; it has three electron microscopes (including the latest JEOL 2000 EX STEM and a scanning electron microscope equipped with a LINK particle analyzer and a 200-kg force deformation stage (for *in-situ* deformation and fracture studies); x-ray diffraction equipment (including a new high-temperature, 2000°C, x-ray diffractometer); a large hot isostatic press (2000°C, 200-MPa pressure and maximum specimen size of 150-mm diameter by 300-mm tall); all types of welding equipment (except electron beam); a weld simulator that can be connected to a programmable servo-hydraulic mechanical testing machine; and two high-energy, continuous wave CO₂ lasers (3 kW and 0.5 kW).

No expense was spared when this department was set up, and--perhaps because of its remote location--the university seems to have remained in favor with Swedish education agencies. About half of the research in Easterling's department is supported by the university, with the remaining half coming from the Swedish Board for Technical Development and industry. Luleå University of Technology is the youngest among Sweden's five technical universities. Founded in 1971, it now has 1200 undergraduate engineering students and a strong postgraduate program.

The rest of this article reviews The Materials Engineering Department's main research programs and a few of the most recent results.

Structural Ceramics

Dr. Harold Herbertson is investigating the mechanisms of sintering in sialon (Si₃N₄ with additions of Al₂O₃ and Y₂O₃) with and without hot isostatic pressing (HIP). These materials are used for cutting tools, bearings, and other applications where high strength at elevated temperatures is required. Herbertson is attempting to identify the various phase transformations that occur in these materials during liquid phase sintering. He is using HIP and will be using the high temperature x-ray diffractometer for these studies. He feels that by HIP he can reduce the required amount of the liquid phase from 10 percent to 1 percent. The amount and structure of the liquid phase material upon solidification controls the properties of the final product.

The program is just beginning, and they wish to hire for 1 year a visiting scientist familiar with the mechanisms of liquid phase sintering.

Dual Phase Steels

Dr. E. Navara has studied the mechanism of austenite formation during the intercritical (dual-phase) annealing step in the production of dual phase C-Mn steels. He appears to have made an important finding for steels containing greater than 1.5 percent Mn. The hardenability of the austenite in the dual-phase mixture is greatly enhanced. This finding is expected to broaden the market for dual phase steels from sheet products to include plate and, perhaps, forgings. This is possible because the most stable austenite for these high-Mn steels is an austenite enriched with Mn. Even though pearlite colonies transform to a Mn-lean, C-rich austenite first, this austenite dissolves, acting as a source of carbon for the Mn-enriched austenite. The nucleation of this Mn-enriched austenite occurs heterogeneously, and it grows by absorbing C and Mn by volume and grain boundary diffusion. This mechanism is active throughout the temperature range investigated, 680°C to 775°C, but the partitioning of Mn to the austenite is very temperature dependent: 680°C, 2.8 percent Mn; 700°C, 2.4 percent Mn; and 725°C, 2.0 percent Mn for a steel containing 1.5 percent Mn. The higher the Mn content of the austenite, the lower the critical cooling rate to form martensite; thus the lower intercritical annealing temperatures will produce the most hardenable material, but the annealing time required to allow the partition of Mn is quite long.

Navara's work not only clarifies the role of Mn in dual phase steel but also indicates that if the Mn content is kept above 1.5 percent and the intercritical annealing temperature is kept low, sections as thick as 10 to 15 mm will transform to the desired microstructure in dual phase steels (ferrite and martensite) with air cooling.

Hot Isostatic Pressing Maps

The concept of deformation maps (a map defining the mechanisms of deformation as a function of the loading conditions--strain, strain rate, temperature, state of stress, etc.) was introduced by M. Ashby (University of Cambridge, Cambridge, UK) several years ago. Since then this idea has evolved to include fracture maps for fatigue, creep, and other fracture modes. Easterling in collaboration with Ashby has developed HIP maps for several materials. As a porous material undergoes densification by pressure and sintering, the mechanisms controlling the rate of densification change with time (as the material

to a consortium led by Standard Telecommunication Laboratories Ltd. (STL), the research and development center of the Standard Telephones and Cables company. Collaborating with STL on the AID project are Data Logic Ltd., British Telecom Research Laboratories, and the Universities of Heriot-Watt, Strathclyde, and Essex.

Using techniques from computer science, artificial intelligence, and cognitive psychology, the AID project will improve man-machine interfaces by enabling them to adapt to individual users. "Help systems" provide valuable assistance to users, but the increasingly complex facilities made possible by advanced technology require more sophisticated user support. The AID project will develop methods of adjusting the system to provide a closer match to the immediate needs of the user. This adaptive interface would allow everyone from the novice to the expert to use products in the way which suits them best. Such products will have a competitive edge because they will be able to serve a wider range of customers.

The goal of the project is to produce tried and tested techniques applied to commercial products such as office systems.

Object Identification From 2D Images

A consortium of four industries, three academic institutions, and the Ministry of Defence will be carrying out a 3-year research program on image analysis and interpretation aimed at the problem of automatically finding and identifying objects in images of complicated scenes. These images can be from sources such as photographs, television, thermal scanners, and x-rays.

Research over the first year will lay the foundations for the first software demonstration. In the second year a number of demonstration projects will be developed to show how the techniques can be used in applications such as parts handling, assembly of printed circuit boards, traffic monitoring, and vehicle recognition. In the third year further development and integration will provide demonstration software with a much greater capability to deal with real problems. Possible applications in the industrial, medical, civil, social, and defense fields include robot automation of flexible manufacturing systems, angiogram analysis for the measurement of heart function, traffic flow analysis, and automatic surveillance for security and defense.

The members of the consortium are British Aerospace Dynamics (Sowerby Research Centre and Hatfield Division),

British Robotic Systems Ltd., STL, Marconi Command and Control Systems Ltd., Plymouth Polytechnic, Bristol University, Rutherford Appleton Laboratory, and the Royal Signals and Radar Establishment.

Speech Interfacing and Phonetic Algorithms

A project on speech interfacing and phonetic algorithms is to be carried out by a consortium led by General Electric Co. (UK), with Plessey Ltd.; Imperial College, London; University College, London; and Leeds University.

Speech interfaces now operate with single-speaker, limited-vocabulary inputs, and the output is of poor quality. The interfaces are not based on fundamental speech knowledge and are approaching the limit of their growth.

This project is concerned with the radical speech work essential to successful commercial development of unrestricted speech recognition and highly intelligible natural-speech output.

2/5/85

Material Sciences

LULEÅ UNIVERSITY--A HOT SPOT FOR MATERIALS RESEARCH IN THE FROZEN NORTH

by Kenneth F. Challenger. Mr. Challenger is the Liaison Scientist for Materials Science in Europe and the Middle East for the Office of Naval Research's London Branch Office. He is on leave until May 1986 from the Naval Postgraduate School, where he is Associate Professor of Materials Science.

The Materials Engineering Department of Luleå University of Technology is at the forefront of research in certain areas of materials sciences just 11 years after its founding.

Established in 1973 by Professor Kenneth Easterling, the department is best known for its research on the physical metallurgy of welding and the development of mathematical models of the welding process. This work is perhaps the best of its kind anywhere. Although less noteworthy, there are research programs on high-performance ceramics, advanced polymers, laser processing of materials, hot isostatic forming, property-microstructure correlations for wood, and some very elegant work in electron microscopy.

Theoretical work on program transformations continues with using the present (and later to be perfected) CIP-S system. In this effort, program development and language definition go hand in hand. This leads to a more precise formulation of notions used in software engineering. In particular, some techniques of program construction may be expressed as transformation strategies.

Work also continues on assuring that the algorithms being developed are absolutely correct in the semantical sense. As follows from the above discussion, this work uses the method of program transformations, and new transformations are added as they go along. Success along these lines will lead to a most impressive increase in reliability.

Bauer, while proudly pleased with the group's progress, also asks the question: does one really need such enormous accuracy in software as they are aiming for? It appears that the answer is: yes, in certain areas. For example, in third-generation chip development and in a variety of military applications. But Bauer has also the perspective to ask: to one do it? The next few years will tell.

ALVEY PROGRAM FUNDS MMI PROJECTS

By James A. Hoffman, The Alvey Program Office, Office of the Secretary of Defense, Washington, D.C.

The UK's Alvey Directorate has announced approval of seven research projects in the man-machine interface (MMI) part of the Alvey program. The Alvey Directorate is contributing £6.8 million (\$7.8 million) to the £10.5 million cost of the MMI projects. (For background on the 5-year Alvey program of research in computer science, see ONR, London, report R-11-84 and ESN 37-12:447-450 [1983].)

Voice-Operated Database

Computers that recognize the human voice are to be developed in a 3-year research project headed by British Telecom's Research Laboratories in collaboration with Logica and Cambridge University.

The aim of the project is to simplify the use of computers for nontechnical people, particularly for tasks such as searching databases. Speech has long been recognized as the most natural and convenient means of communicating

with computers. Voice recognition at the interface between user and machine would enable users to give spoken commands.

Intonation

When humans speak, the point of the utterance is conveyed not just by the words used, but also by which words are accented, and by the way they are accented. Correct placement and vocal pitch is therefore crucial in producing computer-generated dialogue which sounds natural and conveys the real meaning of the message.

A project on intonation in computer-generated dialogue is to be carried out at Sussex University. The goal is to develop rules which associate the purpose of an utterance with an appropriate set of accents and pitch movements, and to embody these rules in a working computer program. In short, the program is supposed to sound as if it knows what it is talking about. The project will also make a start on exploiting the same rules for purposes of speech understanding.

MMI in Command and Control

A consortium of Yard Ltd. of Glasgow, Ferranti, and Strathclyde University has a 6-month contract to investigate and propose areas of MMI research aimed at command, control, and multiple industrial applications.

The project will study the interaction between human and machine in a real-time, decision-making environment, and will emphasize cognitive and communication aspects and performance modeling. Several real-time applications in information organization and decision making are being evaluated. Researchers are considering the use of cognitive modeling techniques for understanding and supporting decision making.

Interactive Computer Systems

The University of York has been awarded a project to study mechanisms for the specification, implementation, and evaluation of interactive computer systems. A research team from the Departments of Computer Science and Psychology will develop methods of ensuring that interactive systems fully meet the needs of their users.

The project will involve the use of formal methods for system specification as well as psychological experiments established to observe the usefulness of formal design properties.

Adaptive Intelligent Dialogues

A 4-year project on adaptive intelligent dialogue (AID) has been awarded

knowledge engineering and expert-system construction. However, it is not a typical *empirical* expert system, but rather one that is fully rational in the mathematical sense; all knowledge in the system is exactly *derived* and strictly valid, based on previously developed and tested algorithms.

Bauer elucidated his philosophy in the following manner. The term "construction" has, in engineering circles, a special connotation: it refers to the building of an engineering product. But in software engineering the term should be taken as a challenging provocation as opposed to tinkering. In fact, "construction" has a more humanistic meaning in geometry: in the spirit of Euclid, Descartes, and other 17th century scientists, the term is indicative of the role rational reasoning should play in "natural philosophy." For a variety of reasons (for example, because with modern technology, software will often be frozen into hardware), bugs in software are rapidly becoming intolerable. Thus, one would expect that rational reasoning plays a top role in the program-production process. Unfortunately, reality is different: "Programs are concocted in moonshine distilleries," says Bauer. "The humdrum day of a programmer is full of alchemy."

The time has come for programming to turn into a safe process of program construction. This means that it must be organized as a sequence of steps of rational reasoning. Starting from an elaborate formal problem specification using elements of predicate logic, set theory, and appropriate algebraic structures, the application of formal rules leads to algorithmic versions and finally to programs oriented toward the instruction repertoire of specific machines.

A genuine program-construction process needs strict formalization throughout. It is a central element of Bauer's program that all versions of a software development (including specifications) can be conveniently represented by one programming language which comprises the complete spectrum of descriptive, applicative, and procedural styles. For it to be maximally effective and sufficiently general, this language must encompass a certain form of nondeterminism which makes the development process transparent and flexible, and it is to be interpreted by some model of the underlying abstract data types. At this point, a program-transformation methodology becomes essential: the use of formally proved transformation rules guarantees the correctness of the interpretation. In addition, the transformational ap-

proach is universal in the sense that the collection of rules can be adapted to any specific application in question. For example, the approach (although it was originally devised for and used with sequential stored-program machines) can be extended to computational models corresponding to the new fifth-generation hardware architectures. Bauer confidently states that this approach of scientific programming methodology elucidates the process, uncovers inherent difficulties, eliminates uncertainties and random decisions, and leads to reliable software.

Research Results

The major results of the CIP group are discussed below.

As noted earlier, central to Bauer's research was the development of a "wide spectrum language," now called CIP-L. The expressive facilities of this must range from descriptive, nonalgorithmic definitions to machine-oriented formulations. Since the methodical aim of the CIP project was to carry out every program-development step by valid transformation rules, the design of CIP-L had to be coupled with the establishment of suitable transformation rules. This approach led, in a natural manner, to a method which defines the language relative to a kernel language by axiomatically given--that is, definitional--transformation rules.

So far, the essential foundations for a language that enables program construction by transformation have been firmly laid by work that included investigations on abstract data types and on strictly algebraic descriptions of programming languages. The work on semantic relations in nondeterministic programming languages, on data-flow concepts, and on parallel programs has been also successfully carried out. Now, the wide-spectrum CIP-L language is given by an abstract syntax based on abstract data types, and it allows several "concrete" dialects. Conceptually, CIP-L is divided into the strictly applicative kernel and a hierarchy of extensions which are reducible to the kernel via definitional transformations.

Recently, work has been also completed on a pilot system for program manipulation and transformation. This system, called CIP-S, operates on the abstract CIP-L language. The prerequisites are now available for developing, under computer assistance, a formally checked transformation system from its specification to a level that allows an immediate transition into an efficiently executable (and even portable) sublanguage of PASCAL.

Summary

The development of polymeric hydrogels by British scientists in Glasgow and London has led to the formation of a company to manufacture and license them for use as controlled-release systems. The hydrogels can be used for stabilization and delivery of drugs in treating human and animal diseases and in agriculture for delivery of pesticides and insecticides. The hydrogels can be tailored to give sophisticated release rates of the incorporated drug over periods of hours to years. There are a number of possible uses in military medicine for which these polymers should be explored.

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Computer Sciences

ALGEBRA, TRANSFORMATION THEORY, AND KNOWLEDGE ENGINEERING REPLACE ALCHEMY AT MUNICH'S TECHNICAL UNIVERSITY

by Paul Roman. Dr. Roman is the Liaison Scientist for Physics in Europe and the Middle East for the Office of Naval Research's London Branch Office. He is on assignment until September 1985.

Information sciences, interpreted in a very broad sense--including also cybernetics and the study of certain

complicated, structured abstract dynamical physical systems--have a distinguished place in the academic establishment of West Germany. Along with large-scale central government research institutes, many specialized university departments contribute work that is often pioneering. (Interestingly, unlike in US and most UK universities, information sciences are not organizationally lumped together with departments of computer sciences.)

Among the oldest and most respected university centers in information sciences is the Institut für Mathematik und Informatik at the Technische Universität München (TUM). One of the first "big" mainframe computers in Europe was built in this institute, using thousands of electron tubes. (Even though the computer has been moved from its original location--which currently serves as the director's office--it is still on display on a corridor, presumably waiting for transfer to the Deutsches Museum.) And it was in this institute that one of the first high-level computer languages, ALGOL, was devised by the director, Professor F.L. Bauer, who, perhaps significantly, switched to information sciences after a successful career in theoretical elementary particle physics.

While ESN has reported on various aspects of computer-program development, I learned from casual discussions (with physicists, for that matter!) that TUM is doing something very unusual and exciting--both in the philosophy of the approach and in the promise of cost-efficiency as well as reliability. Since both high reliability and cost savings are priorities for the US Navy, I decided to visit Bauer's institute. It turned out to be a profitable trip.

First I discussed with Bauer the principal thrust of his special work group within the institute. This group, which calls itself *Programmiermethodik Gruppe* or CIP (short for Computer-Aided, Intuition-Guided Programming), has more than 20 scientists. The group has been supported for the last 12 years by the Deutsche Forschungsgemeinschaft, the German counterpart of the US National Science Foundation, through its special-focus program, *Programmiertechnik*. The participants in the program are with the TUM, the Computing Center of the Bavarian Academy of Sciences, the Faculty of Information Sciences at the Military University of Munich, and the Institute for Reactor safety.

Theoretical Framework

Bauer explained that program construction methodology as viewed in his group is essentially a branch of

The crystalline-rubbery hydrogels are made from a liquid mix which is poured or forced into molds. This is similar to "reaction injection molding." Thus, blocks, slabs, sheets, cylinders, hollow cylinders, and indeed virtually any shape can be molded. In addition, subsequent to polymerization, the materials can be sliced or powdered. The ability to slice is particularly important as the release rate is critically dependent on the thickness in such shapes as slabs. As an example, a 4-mm-thick slab device containing a drug of molecular weight 350 and diffusion coefficient of $2.5 \times 10^{-6} \text{ cm}^2 \text{ s}^{-1}$ in pure water would be expected to release the contained drug over a 24-hour period. This means that almost any drug can be formulated in these crystalline-rubbery hydrogels to deliver on a once-per-day basis. In addition, if reasonably constant delivery is also desired, this can be programmed by the design and polymer composition of these materials.

Another unusual feature of these polymers is their ability to stabilize otherwise unstable materials such as prostaglandins. Working with M.P. Embrey of the John Radcliffe Hospital, Oxford, UK, Graham has shown that prostaglandin E2 when incorporated into a specific dried down crystalline-rubbery poly(ethylene oxide) hydrogel is stable for at least 1 year at 4°C and provides for the first time the possibility of a stable, distributable pharmaceutical dosage form of this material.

Graham and Embrey hope that this ability to stabilize unstable substances will apply to other drugs; and if prostaglandins in general can be stabilized and administered as hydrogel dosage forms, then the replacement of intravenous prostaglandin therapy by oral, transdermal, rectal, or vaginal applications becomes possible. The Office of Naval Research (ONR), Arlington, Virginia, has been supporting research to synthesize prostaglandin Bx (PGBx) for a number of years now. These hydrogels may have some application for containment and delivery in PGBx therapy.

These hydrogels are based on food and pharmaceutical grades of poly(ethylene glycols) registered with the US Food and Drug Administration, and are linked by poly(urethanes), which are components of a number of established prosthetic implants. So the hydrogels are not materials that one would expect to present major toxicity or biocompatibility problems. Indeed, this has been shown to be the case. All tests to date show that these hydrogels are very biocompatible, though not biodegradable.

Biodegradable drug delivery systems present a rather different range of requirements from most of the hydrogel devices discussed above (Wood, 1980). Biodegradable systems are those designed to be implanted or injected and which after a given period of time degrade to soluble products that are taken up and excreted by the body. The hydrogels mentioned above do not break down and must be physically removed if implanted under the skin or in the vagina. However, if given orally or inserted rectally, they are easily passed via the bowel. Research is continuing both in Graham's laboratory and in a number of other places to develop suitable biodegradable hydrogels. Indeed, some have been found and have been tested for delivery of contraceptive steroids in third-world countries. Some have the potential of controlling fertility for as long as 2 years.

It appears that the research on hydrogels may lead to truly programmed delivery as opposed to essentially constant delivery from monolithic devices. It now seems that it will be possible to provide delayed drug delivery under circumstances that require an increasing blood level of a therapeutic agent at a particular time of day--e.g., 5:00 to 6:00 a.m. One need of military medicine could be met if a system could be developed that would release its drug upon the detection of a triggering signal. Such a signal might be the presence in the bloodstream of a particular toxic agent or antigen, or it might be a signal sent in from outside the body by some telemetric method (e.g., an electromagnetic signal). These are problems that have been seen as needing solutions by the ONR program managers. Finally, these hydrogels have been formulated as 10- to 50-nm particles which have some potential for intravenous drug targeting.

Howells not only has been using Graham's hydrogels but also has developed some of his own. Some of these are very slow releasers, providing dosage over a period of a year or more. Howells has recently found that the frequency of administration of antimalarial drugs, such as pyrimethamine, can be reduced from twice weekly to once every 4 weeks using an appropriate hydrogel containing pyrimethamine pamoate. Tests on humans, organized by the World Health Organization, have already given good results. This is another area that has significant potential for military use, in that personnel going into tropical areas where malaria is present can be more effectively protected.

other drug delivery systems, and how they may benefit military medicine.

General Concepts

The use of polymers in pharmaceutical preparations is certainly not new. Both synthetic and natural polymers have seen extensive service as carriers or additives for some time now. Polymeric materials that swell rapidly when in contact with gastric fluid are often used as tablet disintegrants, pH-sensitive polymers are used as enteric coatings, and "inert" plastic (e.g., polyvinyl chloride) matrix tablets have been used for sustained release of drugs for a number of years. The high cost (\$10 million to \$50 million) of bringing a new drug onto the market in a suitable dosage form has led to a great deal of research into providing improved therapy using existing drugs in controlled delivery systems.

There are areas, other than human medicine, in which controlled delivery of chemicals is important. One is in veterinary medicine and the other is in agriculture, where insecticides and pesticides can be delivered in appropriate dosages using polymers and other approaches to controlled release.

There are three things to be considered in therapy using controlled delivery: (1) the duration of the delivery, (2) the delivery site, and (3) the rate of delivery at any given time. Each of these varies in importance depending on the physiochemical properties of the drug and its pharmacokinetic and pharmacodynamic properties in the therapy regime. Controlled delivery has three major advantages: (1) better control of systemic blood levels of the drug being administered, generally with a decrease in adverse side effects, (2) localization of the action of the drug at the target organ, and (3) improved patient compliance with the therapy regime. The desired duration of delivery can be tailored to vary from several hours, as in the case of oral sustained-action formulations, to months or years in some cases. The most sought-after delivery rate is a constant one in an effort to achieve a constant plasma level for optimum therapeutic effect. However, in many cases it is most desirable to have the drug localized in a specific organ, where it acts without being carried throughout the body. Thus, systemic levels are minimized and so too are side effects. Several military medical conditions may lend themselves to a controlled delivery approach which would provide a major advance over current therapeutic modalities. A US Navy program is seeking to develop a system that

not only will target the drug to a particular organ, but also can be activated on demand, and, when not needed, can hold the drug within the confines of the carrier, isolated from the body.

Hydrogels

Essentially, hydrogels are long-chain polymers that are cross-linked to form a mesh that cannot be dissolved even by highly reactive biological compounds (dilute hydrochloric acid, for example). Most materials found in living organisms have some degree of water content and can be considered natural hydrogels (Graham, 1984). Suitable hydrogels for drug delivery should be mechanically strong but not brittle in the dry state, swell at a reproducible rate, and be relatively strong in the swollen state. Among biomaterials scientists, there is a lot of interest in using synthetic hydrogels in manufacturing prosthetic devices and for coating tubes to be inserted into the human body for use as blood vessels. The largest use of hydrogels to date has been in soft contact lenses (Peppas, 1982).

Synthetic polymers tend to be better than natural ones for use as drug deliverers because they can be designed to meet specific requirements and are more reproducible. They can be either of a thermoset or thermoplastic nature, but care must be taken to eliminate toxic residues of monomer, initiator, stabilizer, or drug modified by the polymerization or sterilization process. The most-studied polymers thus far have been those based on acrylamide (Davis, 1974) and its N-sugar substituted derivatives (Akkapeddi et al., 1974), N-vinylpyrrolidone (Hosaka et al., 1979), hydroxyethyl methacrylate (Song, 1981), and poly(ethylene oxide) (Ciba-Geigy, 1978).

Graham and his coworkers in Glasgow have focused their attention on poly(ethylene oxide) hydrogels cross-linked with multifunctional alcohols and diisocyanates which are typical polyurethanes. When they used poly(ethylene glycols) of molecular weights above 2000, the polymers had up to 50-percent crystallinity in the dry state. The crystalline polymer is a material similar to low-density polyethylene in its physical properties. Graham found that in the swollen state this hydrogel released contained drug at a rate proportional to $t^{-1/2}$ as predicted by the theory of simple diffusion from the device into an infinite sink. It is possible to vary the initial and long-term rate of diffusion of drugs from such polymers simply by altering the physical shape.

rhythms are jointly controlled by two endogenous oscillators, one of which controls body-temperature rhythm and is unaffected by exogenous factors, the other controls the sleep/wake rhythm and can be affected by exogenous factors. Normally both run with 24-hour periods, but with altered sleep/wake cycles or temporal isolation, internal desynchronization occurs and the two rhythms separate and run with different periods. Other physiological rhythms appear to run with one or the other of these. However, working-memory performance rhythm appears to separate from both and run with a 21-hour period.

The research technique involves isolating volunteer subjects from natural time cues and then progressively lengthening or shortening their days with artificial time cues over a period of many days (28 in one experiment). Various physiological and psychological variables are repetitively measured over this period.

It is found that performance on simple letter cancellation tasks seems to run with body temperature. With verbal reasoning tasks, however, some subjects show systematic departure from this rhythm, to reach a period of 21 hours. Subsequently performance for some subjects is resynchronized to the temperature rhythm; for others the 21-hour period is maintained, at least within the string of days so far studied. The implication of the individual differences here is that some subjects are more taxed than others by the given task demands, because of differences in mental ability.

In further work with the same paradigm, Folkard reports again that working-memory tasks depart from serial search and body-temperature rhythms. Furthermore, it appears that different subjects use different strategies in tasks at different times of day. And on a syllogisms task, subjects divided into those whose rhythm seemed to follow a 21-hour cycle and those whose rhythm seemed to follow a 27-hour cycle; neither matched the physiological cycles. Further analyses of data collected by another investigator in Sweden also suggested the "post-lunch dip" in both adrenalin and oral temperature that is often experienced, but this occurred in subjects who had not had lunch.

It is clear that both physiological and psychological rhythms can be associated with performance variations both within and between persons. The variations appear substantial and thus of practical concern in military and civilian situations in which performance involving working memory load is critical

even though sleep/wake or time-zone shifts are also inevitable.

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2/15/85

Biological Sciences

HYDROGELS FORM NEW BASIS FOR DRUG DELIVERY IN SYSTEMS BEING DEVELOPED BY SCOTTISH FIRM

by Thomas C. Pozzelli. Dr. Pozzelli is the Liaison Scientist for Biological Sciences in Europe and the Middle East for the Office of Naval Research's London Branch Office. He is on reassignment until August 1988 from the Office of Naval Research, Arlington, Virginia, where he is Program Manager for Bioelectromagnetics.

The British Technology Group and the University of Strathclyde (Glasgow, Scotland) last November jointly invested £250,000 in Polysystems, Ltd. This new company was formed at Strathclyde to manufacture and license hydrogels for drug delivery.

Hydrogels are polymeric materials that have the ability to swell to a high degree in contact with water, yet do not dissolve in water. They have been the subject of intensive research for several years by a team led by Professor Neil Graham in the Department of Pure and Applied Chemistry at the University of Strathclyde and by Dr. Robert Howells in the Liverpool School of Medicine in London. These polymers have a number of unique properties that make them potentially suitable for delivery and controlled release of a number of drugs. Many of the techniques that are being explored could be of significant value in several areas of military medicine. In this article, I will discuss the characteristics of hydrogels, how they are used, what advantages they have over

Table 1 (Cont'd)

<u>Senior Author</u>	<u>Institution</u>	<u>Presentation Title</u>
D.W. Heeley	Univ. of St. Andrews	Meridional anisotropies of orientation discrimination in human vision.
E.C. Poulton	MRC Applied Psychology Unit	Geometric illusions in reading graphs.
M.A. Georgeson	Univ. of Bristol	Spatial frequency masking: integration, non-linear compression or adaptation?
L.J. Evett	MRC Cognitive Development Unit	Orthographic segmentation processes in visual word identification.
A.W. Young	Univ. of Lancaster	Interference between faces and written names.
F. Watts	MRC Applied Psychology Unit	Processing of phobia-related words.
D. Besner	Univ. of Waterloo, Canada	Orthographic and phonological codes in oral reading of Japanese Kana.

and reading ability, but with a substantially impaired auditory memory span not due to apparent input or output deficits. The impairment was shown by various tests to be functionally in the phonological store necessary for maintenance rehearsal and phonological analysis. The deficit did not impair language comprehension. The suggestion is that the normal storage mechanisms involved in auditory memory span tasks are not necessary for fluent speech production or comprehension and that the subject's deficit is more a problem of abstract phonemic awareness and manipulation than it is a structural problem. The results are consistent with Baddeley's working-memory hypothesis.

Sloboda reported a case study of an autistic person of exceptional musical talent--who can memorize and perform complex piano music after only a few hearings, but shows only low normal verbal memory. Most evidence on musical memory suggests that many errors occur in learning and many reconstructions are required; memory appears to be for the gist of a piece, as in verbal memory for text. However, there is sketchy evidence from some musicians and some idiot savants that special memory abilities are involved, and there is the claim that Mozart displayed almost perfect tonal memory. Sloboda compared the autistic individual with a professional pianist in learning complex piano pieces. The comparison was designed to show whether the autistic person had abnormally high memory span for tones, or normal expertise coupled with a narrow window of attention. Thus, tonal (Grieg) and atonal (Bartok) pieces were chosen for

learning. The autistic subject learned the Grieg in four repetitions requiring only 12 minutes, with only minor melody errors, whereas the professional pianist showed good recall of the first eight bars but massive retroactive interference--new sections destroyed memory for earlier sections--and many major harmony errors. However, the autistic subject did relatively poorly, while the professional pianist did relatively well, with the atonal Bartok piece. Analysis of the performances suggested that the autistic subject's ability involves extremely accurate tonal memory, large span, and an internal representation of the music that is highly structured.

Working Memory in Relation to Circadian Rhythmicity in Performance

Folkard discussed new research on circadian rhythms in human performance in the context of his previously published studies (see Folkard, Wever, and Wildgruber, 1983). It is appropriate here to summarize both.

Circadian rhythms are known to exist not only in physiological processes but also in many measures of human performance. The demands placed by a task on the performer's working memory appear to play a large role in deciding the time of day at which it is best performed. Such task demands may also relate to the speed with which performance rhythms adjust to the sorts of changes in sleep/wake patterns involved in shift-work and time-zone changes. A multioscillatory model that applies to physiological rhythms may also apply to these psychological performance rhythms. This model assumes that all circadian

Table 1

Abstract of the Meeting Program for the Experimental
Psychology Society, 3-4 January 1985

<u>Senior Author</u>	<u>Institution</u>	<u>Presentation Title</u>
J.A. Sloboda	Univ. of Keele	An exceptional musical memory.
R.D. Patterson	MRC Applied Psychology Unit	Periodicity detection and the form of musical scales.
J. Edworthy	MRC Applied Psychology Unit	Melodies and the inner ear: a study of musical working memory.
R.P. Carlyon	Univ. of Cambridge	A major breakdown in auditory intensity discrimination.
S. Folkard	Univ. of Sussex	Towards a causal nexus of human psychophysiological variables based on their circadian rhythmicity.
R.J. Phillips	Univ. of Nottingham	Why we need graphs, maps and diagrams.
D.M. Baxter	The National Hospital	Category-specific phonological dysgraphia.
B. Butterworth	Univ. College London	Phonological dyslexia and dysgraphia in a highly literate subject.
R.A. McCarthy	The National Hospital	The selective impairment of verb retrieval and verb comprehension: a single case study of an agrammatic patient.
A.W.K. Gaillard	MRC Applied Psychology Unit	Brain potentials and information processing.
R. Campbell	Univ. College London	The uses of immediate memory.
M. Mishkin	US National Institutes of Health	A neural hierarchy of memory: recognition, recency and recall (the Thirteenth Annual Bartlett Lecture).
D.M. Faulkner	Open Univ.	Fact and fantasy: reality monitoring in the elderly.
W.A. Wagenaar	Univ. of Leiden, The Netherlands	Authorities, risk and the deep structure of decision problems.
R.G.M. Morris	Univ. of St. Andrews	Stereospecific impairment of spatial learning by APV-5, an NMDA receptor antagonist.
D. Christie	MRC Neural Mechanisms of Behavior Unit	The effect of callosum section on motor guidance strategies in a visual discrimination task.
L.C. Simbayi	Univ. of Sussex	Effects of amygdala lesions on taste aversions produced by lactose and lithium chloride in the rat.
C. Pacheau	Univ. Louis Pasteur, Strasbourg, France	Strategies and cues in the Olton maze.
P. Rose	Open Univ.	Wild rats in the wild.
J.N. Williams	MRC Applied Psychology Unit	The effective context for priming.
L. Goward	Univ. of Manchester	Age, speed and stupidity as determinants of recognition memory.

greatest effect even though the Al content of the particles is only 1 percent. The coarsening rate of the (Ti,Al) N particles is much greater than that for TiN.

2. The composition of the precipitates in Ti+V and Ti+Nb steels varies with the size of the precipitate. The Ti content increases with particle size for the Ti+V steels, but decreases with size for the Ti+Nb steel.

3. Following welding, the particles in the HAZ approach pure TiN for both Ti+V and Ti+Nb steels. Strid shows that this behavior is predicted by the equilibrium conditions of a regular solution model involving one interstitial and two metallic elements.

4. He developed a kinetic model for the dissolution of particles containing two metallic elements. By using this model he shows that significant deviations from equilibrium particle compositions can result. Particles containing elements with widely varying diffusivities (Ti and Nb) are governed by kinetic considerations more than particles containing elements of similar diffusivity (Ti and V).

5. This model can be used to describe the coarsening/dissolution kinetics, and thus the grain growth kinetics during a welding thermal cycle. This model predicts that as long as the cooling time between 200°C to 500°C, Δt , is greater than 100 seconds, the particles will reach their equilibrium compositions.

6. The study clearly showed that because of the high temperature stability of TiN precipitates, they are more effective in grain size control during high-energy-input welding. This may be degraded if other nitride forming elements are present without sufficient N to assure that all of the Ti reacts to form TiN (and not the lower temperature carbides). If the C/N ratio is too high, carbon-rich precipitates form which reduce the dissolution temperature of the particles.

The role of inclusions and other precipitates in controlling the microstructure of steels, especially welds, is finally beginning to be appreciated and understood. Studies like this one by Stride are making a great contribution to the development of better materials.

Summary

All phases of Easterling's research have a common theme: Use basic fundamentals of thermodynamics and kinetics to develop semiempirical models of various phenomena that occur during the

processing of materials. These models have been shown to be very useful in understanding the metallurgical changes which result from some very complex processing methods: welding, HIP, and surface hardening. With the use of these models, especially when they are presented in the form of maps or diagrams, basic science is brought to engineers in a format that will help them select parameters of a process to achieve the most desirable material properties. There are many complex processes still to be handled in this way (solidification is an excellent example). I hope that Easterling will continue with his research on mechanism mapping in order for the engineer to take advantage of the materials scientist's understanding of the reactions and mechanisms of many different phenomena which occur during the processing, fabrication, and actual service of engineering materials.

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2/13/86

Mechanics

FLUID DYNAMICS AT THE VON KARMAN INSTITUTE

by Charles J. Holland. Dr. Holland is the Liaison Scientist for Applied Mathematics/Computational Science in Europe and the Middle East for the Office of Naval Research's London Branch Office. He is on reassignment until December 1986 from the Office of Naval Research, Arlington, Virginia, where he is the

Senior Division Director of the Mathematical Sciences Division.

For nearly 30 years the von Karman Institute for Fluid Dynamics (VKI) has been an international center for education and research in fluid dynamics. This article reviews the organization and education programs of the VKI and then concentrates on the recent research directions in aerodynamics. This aerodynamics research, for the most part experimental, is on hypersonic, supersonic, and high subsonic phenomena in applications of high military and industrial payoff.

Background

The VKI, located at Rhode-St. Genese in the suburbs of Brussels, Belgium, was established in 1956 through the efforts of Professor Theodore von Karman, who was then chairman of NATO's Advisory Group for Aeronautical Research and Development. He served as chairman of VKI until his death in 1962, when the institute was renamed in his honor. The VKI was created to bring the European research capabilities in fluid dynamics up to those in the US. With current European research capabilities challenging those of the US, as illustrated by researchers such as Dr. Art Rizzi at the Aeronautical Research Institute (FFA), Stockholm, Sweden, and Dr. Wolfgang Dürst at Lormier, perhaps that need no longer exists. Nevertheless, the VKI continues to be an important center for advanced educational programs in fluid dynamics.

The current director of the institute is Professor Jean Ginoux, who has been associated with the VKI since its founding. Ginoux and Professor J.F. Wadot, dean of faculty and head of the Aerospace and Aeronautics Department, supervise the educational and research programs in the three departments of Aerospace and Aeronautics, Environmental and Applied Fluid Dynamics, and Turbomachinery. There are 12 faculty members in the three departments, with a total staff of approximately 70, including 15 technicians, 10 workers, and 11 administrative.

Mostly, present and past VKI's funding comes from NATO, the nine member-country governments, Germany and FRG, and the participating universities. The institute, which is a non-profit organization, is a member of the International Association of Universities. The remaining funds come from research contracts, in particular, a direct contract with the French government for research in aerodynamics and the support from NATO, which is a major source of funding.

Educational Programs

The activities at the VKI concentrate on advanced educational programs. VKI provides three programs for students holding at least an undergraduate degree in science and engineering. Additionally, VKI provides a short training program for qualified undergraduates as well as a lecture series of 1-week courses. Tuition is free in any of these programs, except for the lecture series, for students from NATO countries providing support to the VKI.

The basic course is the 1-year diploma course comprising lectures, laboratory sessions, and independent research in one of the areas represented by the three departments mentioned above. An independent research project, either basic or applied of an experimental or theoretical nature, forms a major part of the program. Past projects, for example, have dealt with characteristics of low speed wings in slideslip, and rotating stall in axial compressors. Approximately 30 students per year participate in this program, which is intended to prepare students for industrial work or for participation in either of the two advanced programs.

The Advanced Program in Basic Research is a 2- to 3-year program intended to lead to a doctoral degree. The doctoral degree is not awarded by the VKI but rather by a university having an affiliation with the VKI. In most cases, attendance in the VKI diploma course is a requirement for entering this program, although students with a strong background in fluid dynamics may waive this requirement. Approximately 15 students per year participate in this program.

The Advanced Program in Applied Research is a 1-year program for engineers with a doctoral degree or equivalent experience to conduct an advanced program in applied research. This program is intended to develop the skills needed in solving complex fluid dynamics problems of an industrial nature. Typically 10 people are involved annually.

The Short Training Program for undergraduate students, one of the VKI's newer programs, has become the most popular, attracting approximately 75 students for a period of 1 to 3 months. Students become acquainted with the work of fluid dynamicists through participation in a special research project.

Research in Aerodynamics

The Aerospace and Aeronautics Department, headed by Wendt, is undertaking a series of research projects in the hypersonic, supersonic, and high subsonic regions. Most of this work is experimental, which is a reflection of the

research interests of the personnel and the presence of substantial experimental facilities. A new appointment, to be made soon in computational fluid dynamics, will broaden the research capabilities of the department.

Research in hypersonics is being increased as a result of the desire to investigate issues important to the design of proposed new vehicles. Although this research is not funded by specific contracts, it is spurred by several factors. Among these are the French HERMES concept for a manned reusable craft which would ride into orbit on the Ariane 5 launcher, and plans in the US for a military spacecraft which can take off and land horizontally (called the transatmospheric vehicle). Both of these vehicles involve hypersonic speed in reentry for which heat-transfer effects will be extremely important.

A benchmark experimental study on shock-wave and boundary layer interaction is being conducted in the supersonic regime. This experimental research, supported by the US Air Force Office of Scientific Research, is intended to provide accurate experimental data in a complex flow situation to test the validity of various existing computational algorithms. In the past it has been difficult to obtain both experimental and numerical data under the same initial and boundary conditions. In this experimental work, Wendt reported that he had been able to obtain laser Doppler velocimetry measurements within 0.1 mm of the surface of the object.

The high subsonic research is investigating the effects of compressibility on vortical flows from a delta-wing structure. Even at free Mach stream numbers of only 0.5, they have observed embedded shock structure for flows over the wing surface. These experimental observations are consistent with some recent computational work of Dr. Art Rizzi of FFA, who has also "observed" these embedded shocks using his three-dimensional Euler codes.

There has also been some recent work on reducing after-body drag due to vortex flow fields with a consequent decrease in fuel consumption. Military transport aircraft, such as the C-130 and the C-141, are particularly susceptible to this problem because of the highly upswept afterbody. Wendt stated that their experimental results had led to some retrofit plans by Lockheed-Georgia on the C-130.

Conclusion

The VKI serves an important dual role of training and research in fluid dynamics. In particular, important

experimental work in aeronautics is being conducted; the results should be useful in the design and operation of future aeronautical systems.

8/18/85

LEBUS AT SALTSJÖBADEN

by Patrick Leehey. Dr. Leehey is the Liaison Scientist for Naval Architecture and Applied Mechanics in Europe and the Middle East for the Office of Naval Research's London Branch Office. He is on leave until September 1985 from the Massachusetts Institute of Technology, where he is Professor of Mechanical and Ocean Engineering.

Large eddy breakup devices (LEBUs) were a principal topic for discussion at the EUROMECH 181 colloquium. Thin ribbons placed in tandem across the outer portion of a turbulent boundary layer provide marked reduction in frictional coefficient, but a total drag reduction of at most 5 percent experimentally to date.

Background

Drag reduction in turbulent boundary layers was the topic of EUROMECH 181, held at Saltsjöbaden, Sweden, from 29 through 31 August 1984. EUROMECHs are scheduled by an applied mechanics colloquium committee chaired by Professor G.K. Batchelor of Cambridge University on various special topics in applied mechanics at various research activities and universities throughout Europe. They are intended to encompass a specific topical area of current interest and to be limited in attendance to people involved in ongoing investigations related to the subject. The meetings are quite informal, and it is not customary to publish the proceedings of the meetings. Attendees are encouraged to present ongoing research which has not yet reached completion. Approximately 40 investigators attended this meeting; nearly half came from Sweden, but there was good representation from West Germany, England, The Netherlands, and Switzerland. I was the only US participant.

Drag Reduction

Various techniques for drag reduction are currently being investigated. I reported on techniques for delaying transition from laminar to turbulent

flow in AIAA 39-3:96-99 (1985), and on the use of longitudinal riblets in AIAA 39-2:60-61 (1985). These were also discussed at EUROMECH 181, but little beyond the previously reported information developed. Nothing was reported at this meeting on the use of long chain polymers in the boundary layer or on the use of compliant coatings beneath the boundary layer. There was only one paper related to suction. I shall therefore report here on the papers related to the use of large eddy breakup (LEBU) devices for the reduction of turbulent boundary layer drag. Here the European fluid dynamics community is quite active.

In its earliest concept, a LEBU was a very porous structure placed in the outer portion of a turbulent boundary layer. The purpose of this device was to break up the large-scale eddies which are considered to be responsible for the substantial injection of irrotational fluid from outside of the boundary layer deep into the boundary layer. It was felt that if this process could be impeded, then the frictional drag at the wall could be substantially reduced.

Some of the earliest investigations were conducted at the Illinois Institute of Technology (IIT) by H.M. Nagib and his coworkers (Corke, Guezennec, and Nagib, 1980), and by D.M. Bushnell and his colleagues at the National Aeronautics and Space Administration (NASA), Langley, Virginia (Hefner, Weinstein, and Bushnell, 1980). Both groups found that a lattice-like structure of ribbons stretched laterally across the outer portion of a turbulent boundary layer resulted in some reduction in the local frictional resistance coefficient sufficiently far downstream behind the device. The local skin frictional resistance coefficient is defined as the ratio of the local shear stress on the boundary to the free stream dynamic head. Reduction of frictional resistance is not the whole story, however, for there is drag on the LEBU itself. For these earlier lattice configurations, the device drag greatly exceeded the reduction in the streamwise-integrated wall frictional resistance. It then appeared that a tandem two-ribbon configuration should have lower device drag, partly because the after ribbon would be in a lower speed wake created by the forward ribbon. Figure 3, discussed in detail later, shows a tandem LEBU in place in a turbulent boundary layer. Initial tests of a tandem LEBU by the IIT group showed some 15-percent reduction in the local frictional drag coefficient C_f commencing immediately behind the device and extending downstream for a distance equivalent to at least 50 boundary layer

thicknesses (Corke, Nagib, and Guezennec, 1982). The results further indicated 15- to 20-percent total drag reduction. The IIT experiments were repeated at NASA, Langley, by Bushnell and his colleagues. They could not reproduce the IIT results, finding instead only 6-percent total drag reduction. Moreover, the frictional resistance reduction immediately behind the device developed gradually rather than abruptly. Nevertheless, the tandem configuration today seems to be the most promising and was the sole type of LEBU discussed at EUROMECH 181.

The Joint Swedish-Swiss LEBU Program

A joint program investigating the development and application of LEBUs is being conducted by the Aeronautical Research Institute of Sweden (FFA), Bromma, Sweden, and the Laboratoire de Mécanique des Fluids, Swiss Federal Institute of Technology (EPFL), Lausanne, Switzerland. Figure 1 typifies one of the earlier experimental results obtained in the EPFL subsonic wind tunnel using tandem LEBUs. In Figure 1, dx is the separation between the ribbons trailing edges, L is the length of a single ribbon, t is the ribbon thickness, and h is the height of the tandem ribbons above the wall, all expressed in millimeters. The local skin-friction coefficient is given in the ordinate, and the distance downstream of the trailing edge of the LEBU in millimeters is given in the abscissa. The tunnel fan

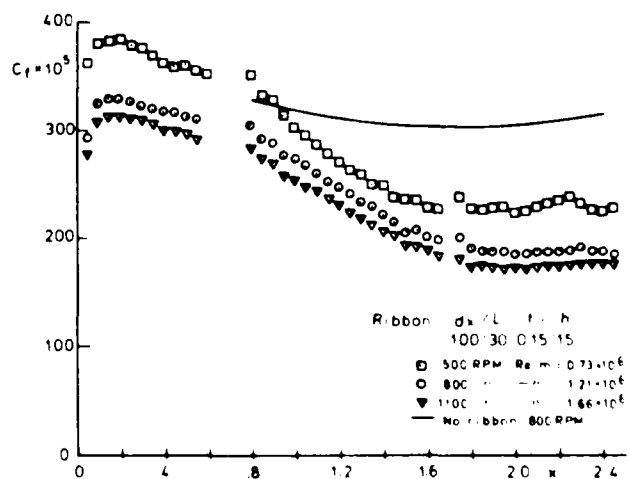


Figure 1. Local skin friction as function of position ($dx/L = 2.333$, $t/h = 0.15$ (from Bertelrud, Truesd, and Avellan, 1982; reproduced by permission of the American Institute of Aeronautics and Astronautics, Inc.).

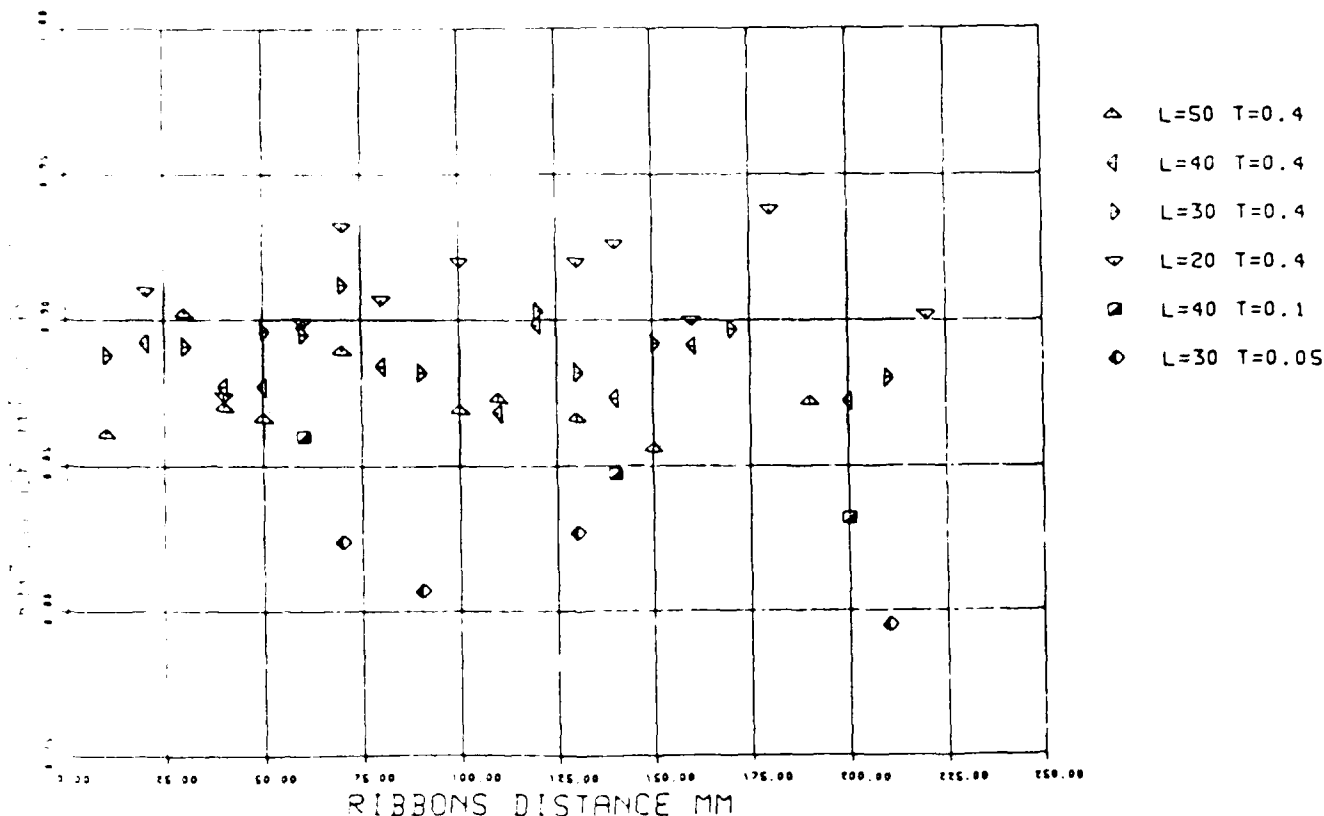


Figure 2. Ratio C_f at 2.45 m for different configurations, $L/DX/T/H \approx 15$ mm.

up's are directly proportional to the free stream velocity in the wind tunnel. The local frictional coefficient C_f was determined using Preston tubes. This is satisfactory sufficiently far downstream of a LERU where the flow has returned to similarity. In principle, the measurement of the streamwise gradient of the momentum thickness of the boundary layer would be correct everywhere behind the LERU. Such a measurement was not used because a different run would be required to measure a velocity profile at each downstream position. Thus, repeatability of results would be in question. It is difficult to get an accuracy better than 2 to 3 percent by either method. Moreover, the measurements are also plagued by difficulties with transverse variation in the skin friction coefficient. Nevertheless, it is quite evident that a prolonged region of significant reduction of the skin friction coefficient can be obtained.

M. Veuye and T.V. Truong presented the most recent information from EPFL which resulted from a systematic variation of the tandem LERU dimensional parameters. The results of this recent investigation are summarized in Figure 2. Here the ratio of the local

frictional coefficient with the LERU in place to that without is given in the ordinate. The abscissa is the gap DX between the two ribbons. Data are given also for various ribbon lengths L and thicknesses T . All data are for a ratio of height of the LERU above the wall to the total boundary layer thickness equal to 0.68. We see the following facts from Figure 2: (1) 5- to 20-percent reduction in local frictional coefficient C_f was obtained; (2) the ribbons with the minimal thickness T performed better; (3) the results for different ribbon separations DX were inconclusive; and (4) there is a spatially periodic variation in the local frictional coefficient C_f going downstream. It is of interest that this period is essentially the same as a separation DX of the ribbons. In the earlier experiments at EPFL, one tandem configuration gave 5-percent net drag reduction, based upon a comparison of momentum thicknesses θ at the furthest downstream measurement position of 2.45 m from the LERU trailing edge (Bertelrud, Truong, and Avellan, 1982). This configuration had dimensions $L/DX/T/H = 10/27/.05/15$ in millimeters. Total drag change was not reported for the most recent test configurations.

Truong and Veuve of EPFL and A. Bertelrud of the FFA reported their most recent results in the construction of a similarity scheme for determining the mean velocity profile development behind a LEBU. This semi-empirical scheme involves the use of: (1) a law-of-the-wall representation attributable to van Driest, (2) a Gaussian ribbon-wake profile, and (3) for the outer boundary-layer wake region, a Thompson profile modified by Sarnecki's intermittency function. This scheme is not used to predict drag reduction, for the local friction coefficient C_f is an input to the scheme; it is intended rather to facilitate comparisons between various LEBU configurations, to provide an initial input to a computational fluid dynamics study, and finally to estimate the effect of mean pressure gradients on LEBU performance. Their results show that a remarkably good comparison was obtained between the calculated mean profiles, in accordance with the similarity scheme and experimental results, spanning the range from directly behind the LEBU until the LEBU wake was no longer discernible.

Bertelrud reported on a very interesting series of full-scale experiments with a LEBU on a SAAB 32A Lansen swept wing attack aircraft. The wing of this aircraft has a leading edge sweep of 39 degrees and a symmetrical NACA 64A010 section normal to the 35-degree swept 25-percent chord line. It has zero twist. A tandem LEBU was installed at 15-percent chord paralleling this chord line over approximately a quarter of the wing span. Frictional coefficients were measured back to 80-percent chord. Measurements were made from a flight Mach number $M = 0.92$ down to stall. The LEBU elements were not flat ribbons but were cambered airfoil sections with the lift directed toward the wall. This is a very desirable feature to reduce the element drag. Depending upon flight conditions, the LEBU was installed from 44 to 80 percent of a boundary layer thickness. Unfortunately, the gap between elements was less than 3.5 times the boundary layer thickness, whereas the preferable value is on the order of 16 according to NASA, Langley, experiments. However, the major purpose of this test was to determine the characteristics of LEBUs in full-scale operation to see whether the devices are in any sense unsuitable. The principal results of the full-scale flight program to date are as follows:

1. About 10- to 15-percent local frictional coefficient, C_f , reduction was obtained. (It should be noted,

however, that this was obtained at very high Reynolds number, Re_θ , based on momentum thickness, θ . The values ranged from 8000 to 14,000, which should put to rest conjectures made in the past that LEBUs might be totally ineffective at high Reynolds number).

2. Pressure gradient compressibility and small three-dimensional flow effects did not adversely affect local friction reductions.

3. Overshoot occurred on the aircraft--i.e., the local frictional coefficient sufficiently far downstream behind the LEBU was in fact higher than it would have been without the LEBU present. As a result no total drag reduction was obtained with the device as installed.

4. No effect on handling characteristics of the aircraft in any part of the flight envelope developed. This was significant because it had been feared beforehand that the LEBU might adversely affect shock/boundary layer interaction.

Experiments at the Cavendish Laboratory

A.M. Savill reported on LEBU experiments conducted at the Cavendish Laboratory of Cambridge University, UK, in two different wind tunnels. One was equipped with a skin friction balance for direct measurement of skin friction downstream of a LEBU. The balance was in fact fixed in the tunnel and the LEBU located at various positions forward of the balance. The other wind tunnel was equipped with a combined laser sheet and white-light-beam, smoke-flow visualization together with a capability for hot-wire measurement for performing detailed studies of the flow behind a LEBU. Although no net drag reduction has been found as yet in the Cambridge experiments, the flow visualizations give possibly one of the clearest pictures of the mechanism of the operation of the device yet obtained.

Figure 3 shows how a tandem LEBU placed in the outer portion of a turbulent boundary layer operates. First we consider a turbulent boundary layer in the absence of a LEBU. Its outer structure consists of a row of horseshoe vortices inclined approximately 45-degrees downstream to the flow. These vortices interact with a slow mutual overturning, causing an entrainment near their peaks with the outer irrotational flow. The horseshoe vortices themselves develop from the longitudinal streaking occurring at the wall boundary layer and the subsequent bursting in the sublayer. The entrainment of the outer irrotational flow is considered to form an essential part of the feedback mechanism by which the sublayer bursting is maintained.

TWIN TANDEM 3" PLATES

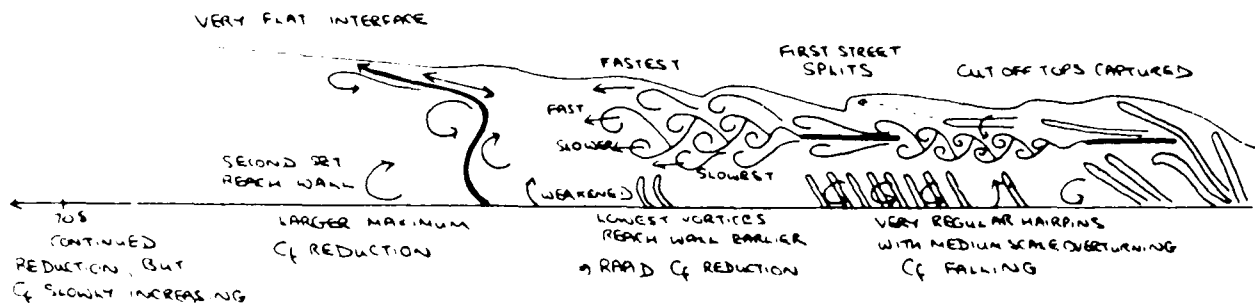
 $h = 0.85, S = 55$ 

Figure 3. Operation of tandem LEBU in outer portion of turbulent boundary layer (Mumford and Saville, 1983; reproduced by permission of the American Society of Mechanical Engineers).

(Precisely how this occurs is a matter of some controversy.) Next, suppose that a tandem LEBU is installed in the outer portion of the boundary layer. When a horseshoe vortex encounters the leading edge of a ribbon element, it is stretched over the element to such an extent that it is effectively severed. It is this action that gave rise to the name LEBU itself. However, Savill and his coworkers have found that the wake of the element or elements of the LEBU is equally or more important in the overall process. A ribbon element develops a very finely spaced vortex street wake. It is this wake that forms a barrier between the outer portions of the cut horseshoe vortices and the inner residual structure (Figure 3). Two things happen: first, the intermittency of the outer portion of the boundary layer is greatly reduced with a consequent reduction in entrainment of irrotational flow; second, the vortices cause an upwelling of flow in the immediate vicinity of the wall, with consequent reduced frictional resistance. It is for this reason that the Cambridge group dislikes the word LEBU, and prefers the term manipulator. Tandem LEBUs appear superior to a single one because the vortex street from the upstream element impinges upon the after element, creating a double vortex wake which provides a more effective barrier than a single one. On the other hand, the frictional resistance of the two elements that are separated is in fact higher than it would have been if the two elements were without gap, the device drag being increased by approximately 32 percent. There is, however, the possibility that the vortex street from the upstream

wing element can produce just the right oscillatory effect upon the after element such that a thrust component on the after element evolves reducing the total device drag. This is sometimes termed the Katzmayer effect. It is readily calculated from linearized unsteady airfoil theory by determination of the net leading edge suction.

Concluding Remarks

Although European efforts at turbulent boundary layer manipulation by LEBUs have been intelligently developed with very considerable physical insight into the process, results in terms of total drag reduction to date, about 6 percent, are somewhat meager. Separation of the various drag contributions is quite difficult, and it is complicated by transverse variations. The overshoot effect is particularly troublesome, and it may well be necessary to install additional LEBU devices every 80 to 100 boundary layer thicknesses downstream in order to prevent this. Occasionally the investigators get a bit discouraged about the possibility of recouping the device drag and obtaining net reductions. Mumford and Savill (1983) state that "estimates of potential gains are such that one is beginning to wonder if there is some overall principle involved which prevents this." This was just temporary discouragement. Certainly more attention can be given to the reduction of device drag by the use of proper thin-airfoil sections. It might be helpful to mount the manipulators directly on a floating-element drag gauge in order to determine the local combined effect of device drag and immediate downstream wall frictional

efficient. Finally, there may be special applications in which the manipulators will really come into their own. Savill points out that for flows with very large free-stream turbulence, the buffer effect of the wake of the manipulator could possibly prevent the normal increase in friction coefficient C_f due to the free stream turbulence. This might be quite important in internal flow applications. Further, since the LBBU operates in the outer portion of the boundary layer it appears that its effects can supplement those of riblets, whose mechanism clearly depends on inner viscous scales (see ESN 39-2:60-61 [1985]). Thus, the two devices, operated together, could possibly produce a net drag reduction superior to each one operated individually. Apparently work in this direction is already under way.

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Two important technical meetings on ship hydrodynamics were held in September 1984. This article covers highlights of the 15th Symposium on Naval Hydrodynamics, held in Hamburg, West Germany, and the 17th International Towing Tank Conference, held in Göteborg, Sweden.

Naval Hydrodynamics Symposium

The main purpose of the symposium was to provide an international forum for the exchange and discussion of advanced research results in the field of ship hydrodynamics, with emphasis on four topics of current interest: (1) seakeeping problems, (2) hull-propeller interactions, (3) nonlinear free-surface problems, and (4) frontier problems in hydrodynamics.

The symposium was sponsored by the US Office of Naval Research (ONR), the US National Research Council, and the Hamburg Shipbuilding Research Institute (HSVA).

One of the technical highlights of the symposium was the Weinblum Memorial Lecture, presented by Professor Marshall Tulin of the University of California at Santa Barbara. Tulin discussed surface waves from the point of view of rays. The ray theory, which made a significant contribution in the physics of optics, can be applied to explain the complex wave systems generated near a ship bow. A brief review of the state of the art in the application of geometric ray theory to ship waves was given. Tulin then offered suggestions for avenues of further development of the ray theory that may shed light on nonlinear ship-wave reflections.

In the sessions on seakeeping problems, several new and impressive developments were reported. A paper by Lin, Newman, and Yue discussed an innovative numerical scheme which can correctly demonstrate the process of the detachment of the free surface from a vertical wave maker in horizontal oscillation. The free-surface breaking as the consequence of the flow detachment is a complex nonlinear phenomenon which never has been satisfactorily modeled by the existing theoretical/numerical methods. The investigation is being supported by the ONR Ship Hydrodynamics Special Focus Program, and further extension of the investigation will be continued under ONR support.

In the sessions on propeller-hull interactions, one of the highlights was the paper given by Jessup, Schott, and Jeffers (David Taylor Naval Ship Research and Development Center [DTNSRDC], US). The paper described the method of measuring the local propeller blade

1984 SHIP-HYDRODYNAMICS MEETINGS

by Thomas M. Lee, Jr. is a Technical Officer in the Mechanics Division, Office of Naval Research, Arlington, Virginia.

flows by using a laser-Doppler-velocimeter (LDV) technique. It is not easy to measure the flow velocities by an LDV device and the pressures by miniature gauges on a rapidly rotating model-propeller blade. The authors mainly presented sample results obtained from a three-bladed standard model propeller and compared some of the results with computed results. The fact that such measurements can be made on rotating propeller blades impressed the audience a great deal.

Full-scale ship wake measurements in front of rotating propellers by an LDV device were reported by Kux and Iaudan of HSVA. The measurements made on two cargo ships--the *Sydney Express* and the *St. Nikolaus*, owned by German shipping companies--were compared to those obtained from the model tests. Only a qualitative agreement between the two results was obtained, indicating the need for further extensive investigations to resolve the complex scaling law between the model and the full-scale ship wakes. In the discussion of this paper, it was clear that many full-scale ship wake measurements have been undertaken by the British Ship Research Association and the Canadian Research Council. DTNSRDC sent an observer to those full-scale measurements. Power-efficient and quiet propulsors are much desired for commercial as well as naval ships. Without knowing the actual flow field in which a propeller is to be operated, it is difficult to design with confidence a propeller which meets the ever-narrowing margins for powering, noise, and vibration. Thus, major maritime nations probably will continue vigorous research on predicting full-scale ship wakes.

In the session on nonlinear free-surface problems, a majority of the papers were related to ship-bow flows. Fry and Kim (DTNSRDC) presented extensive bow-flow measurements by an LDV device, along with calculated results based on the linearized free-surface boundary conditions. The LDV device used was capable of measuring simultaneously all three vector components of flow velocities at a point in the flow field. It was the first result ever presented showing all three velocity components of the bow flow-field of ship models. The agreement between the measured and computed results was impressive, particularly for the cross-flow velocities, in the bow region up to about 7 percent of the model length aft of the bow. The streamwise velocities and the free surface elevations on the hull were not in such good agreement as in the case of the cross-flow velocities after 4 percent of model length.

Mori (Hiroshima University, Japan) presented an interesting paper on the neck vortex and bow wave around blunt bodies. One of his conclusions was that the free-surface curvature ahead of a blunt bow has a significant effect on the breaking waves. By introducing a submerged bow bulb, which reduced the surface curvature, he experimentally demonstrated that the breaking of waves can be significantly reduced. His research is a good example of a successful combination of theoretical and experimental investigations.

Tuck (University of Adelaide, Australia) and Vanden-Broeck (University of Wisconsin) presented a theoretical paper on searching for a bow shape which does not create waves in two-dimensional flow. The main objective of the paper was to demonstrate numerically that there exists a bow geometry for a given two-dimensional uniform flow which does not create bow waves. The bow shape they found has a bulb-like geometry below the free surface.

Takekuma (Nagasaki Experimental Tank, Japan) and Eggers (Institut für Schiffbau, West Germany) investigated the effect of bow shape on bow-wave breaking. Both theoretical and experimental investigations led them to conclude that a bow form with fine entrance angle and protruding bulb is effective in reducing the necklace vortices around the bow.

Dagan and Miloh (Tel Aviv University, Israel) presented a highly mathematical paper investigating nonlinear resistance by a Zakharov-type integral equation. This paper showed a potential theoretical approach in tackling the nonlinear wave resistance of a ship.

Ertekin, Webster, and Wehausen (University of California at Berkeley) presented a paper on ship-generated solitons. The theoretical results obtained by using the Green and Naghdi theory on directed fluid sheets were compared with the computed results of Wu of the California Institute of Technology for a two-dimensional pressure patch moving on the free surface of a rectangular tank of very shallow water depth.

In the session on frontier hydrodynamic problems, Isshiki and Murakami (Hitachi Shipbuilding Co., Japan) and Terao (Tokai University, Japan) presented a paper on an innovative concept of the so-called "wave devouring propulsion." The concept is based on the principle of fish locomotion and bird flights by an oscillating lifting surface. The researchers have shown by towing tank experiments that a floating body with submerged hydrofoils can propel itself in the opposite direction to

the wave propagation. The authors suggest that such a device may be applicable to floating ocean platforms to counteract the wave-induced drifting.

Chen and Patel (University of Iowa) showed their new approach to computing the thick boundary-layer flows in the region of a ship's stern. They used a time-marching solution of the partially parabolic version of the Navier-Stokes equations. The body grid generation and the "finite-analytic" numerical scheme in solving the partially parabolic equations were elaborately described in the paper. It appears that before a practical numerical integration of the full Navier-Stokes equations is available, such an approximate approach by the partially parabolic method may be an appropriate means to satisfy our immediate needs for understanding the flow behavior near ship sterns.

The symposium revealed that substantial advances are being made internationally in ship hydrodynamics research. New numerical schemes for solving the nonlinear free-surface/body interaction are now beginning to emerge. The LDV device is providing a new approach to flow zones that so far have been untouchable--such as the ship bow region and the zone between the propeller and the hull. The nonintrusive nature of the device makes it possible to measure the flow velocities in these zones. Such a device with further improvements applied to the measurements of flow around full-scale ships will contribute significantly to the understanding of the law of dynamic similitude between a model and its mother ship. The current ship hydrodynamics research appears to be placing more emphasis on the local flow phenomena than on the usual global quantities such as total hydrodynamic forces acting on a ship. This trend is demonstrated by the numerous participants' keen interest in the bow and stern flows. The free-surface breaking by a ship bow not only increases the drag but also significantly affects the flow around the entire ship. For instance, the bubbles generated by free-surface breaking can flow along the stern of a ship and could cause an early inception of propeller cavitation. It appears that in 5 to 10 years propeller designers will have better descriptions of propeller inflow so that they can design fully wake-adapted propellers.

The US is maintaining its leadership in ship hydrodynamics research; however, traditionally strong maritime nations such as Japan and the northern European countries are achieving rapid

progress in ship hydrodynamics research for commercial ships.

Towing Tank Conference

The primary objective of the International Towing Tank Conference (ITTC) is to stimulate progress in solving technical problems associated with towing tank experiments and also to stimulate research in all fields in which a better knowledge of the hydrodynamics of ships and marine installations is needed. To help fulfill this aim, the following actions are normally taken: (1) recommending standard procedures for general use in carrying out ship- and marine-installation model experiments, (2) formulating collective policy on matters of common interest, and (3) providing an effective organization for the interchange of information on such matters.

The major events of the conference were the sessions featuring reports from 10 technical committees: Resistance, Propeller, Cavitation, Performance, High-Speed Marine Vehicle, Maneuverability, Seakeeping, Ocean Engineering, Information, and Performance in Ice-Covered Waters. The reports presented by each technical committee were products of 3-year investigations of the subjects chosen by the previous conference, held in Leningrad in 1981. The subjects covered almost all ship hydrodynamics problems of current interest, ranging from traditional problems such as ship resistance to pioneering problems such as ice modeling in towing tanks. (The details of the committees' reports are given in the proceedings of the 17th ITTC.)

One interesting problem involves the uncertainties in the governing hydrodynamic similitude laws between a prototype and its full-scale ship. Such problems are more frequently encountered in modeling the viscous resistance, cavitation, and propeller inflow. The scaling problem is also found in ice towing tanks. In the past few years, a number of ice towing tanks have been built throughout the world, reflecting the need to learn more about ship performance in icy waters. However, many scientific questions--for example, about ice modeling and scaling--need to be answered before any standard model testing techniques can be established internationally.

The problem of ship resistance in shallow water drew lively discussions. The phenomenon of generation of solitary waves by a ship in a canal of shallow water depth and the associated unsteady resistance seems to be drawing

a great deal of scientific interest internationally among the ship-hydrodynamics researchers. New measuring techniques in cavitation tunnels were reported. Measurements of the size of microparticulates in water tunnels and cavity thickness by LDV (West Germany, Japan) and light scattering (Japan) indicated a promising advance in cavitation research.

The conference plays an important role--it helps promote international cooperation in investigating the technical problems of common interest in marine hydrodynamics and in reporting findings. The 18th ITTC is scheduled to be held in Japan in the fall of 1987.

507747

Physics

LASERS AND LASER ACCELERATORS AT RUTHERFORD APPLETON LABORATORIES, UK

by Paul Roman. Dr. Roman is the Liaison Scientist for Physics in Europe and the Middle East for the Office of Naval Research's London Branch Office. He is on assignment until September 1987.

Advanced methods for generating front-line laser systems and ultra-high-energy and high-intensity beams of charged particles are the focus of several projects of the Central Laser Facilities (CLF) at the UK's Rutherford Appleton Laboratories (RAL). During my visit in late November, I talked to people both inside and outside the laser group who are developing these novel and hopefully revolutionary methods.

Background

RAL, near Didcot, Oxfordshire, is located on a modern site adjacent to the historic Harwell atomic energy establishment, employs over 1500 permanent personnel, and has an annual expenditure of more than £52 million (about \$62 million). The laboratory's major responsibility is to act as a large-scale central facility in service of nationwide university research. Many scientists from both British and foreign universities spend extended periods of time carrying out projects that require equipment not available to single academic

institutions. Many projects, as well as the operation of RAL, are directly sponsored by the UK's Science and Engineering Research Council (SERC).

Laser Development and Research

The SERC-supported CLF was established in 1975. The main themes of current research can be broadly summarized as follows:

1. Laser development. Improvement and enhancement of an ultra-high-power, versatile, Nd/glass laser system (VULCAN). Further development and enhancement of a high efficiency fluoride gas laser (SPRITF). Expansion and maintenance of an ultraviolet (UV) radiation facility.

2. Plasma physics. Study of ultra-dense, strongly interacting plasmas of high net ion charge. Nonlinear interaction of high-intensity laser beams with matter, parametric instability, relativistic corrections. Energy transport in plasmas, heat flow studies, photonic energy transport. Laser generated implosions, dense plasmas, inertial confinement.

3. Short wavelength research. Application of UV lasers in plasma physics. Multidisciplinary work with repetitively pulsed and frequency tunable UV lasers in physics, chemistry, biology, and materials processing. Application of UV lasers to lithography and related problems in nonlinear integrated optics. X-ray laser development using inversion in laser-generated plasmas or induced by x-ray pumping from another laser-pumped plasma.

The following discussion is restricted to recent developments and plans in connection with the laser facilities, since most of the particularly interesting research with laser beams is done by university research groups using the RAL facilities. This research will be reported in later ESN articles in connection with specific visits to the relevant universities.

The VULCAN Nd/glass laser was designed primarily to be a very versatile machine. At its heart are two synchronized oscillators, so that simultaneously a "long" pulse (with duration between 0.1 and 25 ns) and a synchronous "short" second pulse (with duration that can be varied between 70 ps and 1 ns) can be produced. This feature makes the system unique. The two pulses are independently amplified and can be fed in any configuration into two output channels. In one prepared target area these two outputs appear as a six-beam, symmetrically

placed output (for uniform, symmetric plasma experimentation) plus one separate beam, while for another target area there are two single-beam outputs available. A major improvement project is currently being implemented: the researchers are going to a 12-beam system which is hoped to be fully operational by late spring this year. After improvements made in late 1983, the researchers now use two chains of rod amplifiers, each containing six stages, and then each of the six beams (12 within a year) go through separate disk amplifiers. Each of the current seven output beams has a similar performance with up to 150 J available in 1-ns pulses (or 50 J in 100-ps pulses). Thus, a total of 1.5-kJ maximal energy can be concentrated in the present multi-beam system. Consequently, power levels of 4 TW have been achieved, which makes VULCAN the most powerful laser system in Europe. With the alterations in progress, a total energy of 30 kJ will be soon achieved in the 12 beams so that only the Livermore NOVA (which just became operational) will supersede it. The repetition rate is 1 in 30 minutes in regular operation. The fundamental wavelength is 1.05 μm (nominal). But the second (0.53 μm) and third (0.35 μm) harmonics are now also routinely used, and the fourth (0.26 μm) is soon likely to become more than an experimental achievement. The proper operation of the 0.53- μm -wavelength setup is particularly important for x-ray laser experiments scheduled for next year. Another improvement, now in progress, is the installation of more efficient line focus optics. This is also important for the planned x-ray laser experiments.

It may be interesting to compare the RAL ultra-high-power laser development project of VULCAN to that of the ASTERIX project at the Max Planck Institute (MPI) at Garching (ESN 39-4:165-169 [1985]). The MPI--after previous work with a large Nd/glass laser system--felt that while energy increase is possible, efficiency would soon reach a limit. Therefore, researchers at MPI decided to develop a new idea--namely, that of the iodine atom laser. They succeeded, and their expectation of greatly increased efficiency was justified. On the other hand, RAL followed the example of the USSR and France, and in particular relied very much on the glass laser development at Livermore. They felt that for them, it was safer to follow and improve existing designs than to develop an entirely new laser. The availability of international expertise, including

Japanese scientists, made their approach both prudent and successful.

The second remarkable laser at RAL is the very-high-power KrF gas UV laser SPRITE. It is pumped by an electron beam of 0.75-MeV energy. This UV laser is a pioneering machine in a worldwide context. Currently it produces 250-J pulses of approximately 60-ns duration. This corresponds to about 4-GW average power. The wavelength is 249 nm. The available power supply limits presently the repetition rate to 1 per 5 minutes. The beam has a large, 25-cm diameter and, by using an unstable resonator cavity, RAL has succeeded in producing a highly focused beam of only 100- μrad divergence. There are ambitious plans to considerably improve the system in the near future. In this work, SPRITE will be used as the main power amplifier in a new laser system currently under construction. The goal is to produce 150- to 200-J pulses of only 1-ns length, corresponding to about 200-GW power. The output will be divided into eight beams, concentrating their energy in a symmetric arrangement onto a target. The feat will be achieved by compressing the presently available power by a combination of angular optical multiplexing and Raman amplification in gaseous methane. The output wavelength will be increased a bit to 268 nm since this is the first Stokes-Raman wavelength of CH_4 . There are long-range plans to ultimately achieve an output of several kilojoules.

The current interim system has been tested successfully and applied recently, for example, for producing very efficiently x-rays in laser plasmas.

Dr. R. Evans, a senior member of the group who showed me around, offered an interesting aside; he said the lab got into fluoride laser development because the US Department of Energy stopped anticipated further development in this area, and "somebody had to do it."

Beat-Wave Laser Accelerators

It is now almost a quarter of a century since the first proposal was made to use a laser for accelerating charged particles to extremely high velocities. Subsequently a large variety of proposals were put forward. These can be grouped into categories like near-field accelerators, far-field accelerators, inverse Cherenkov accelerators, and beat-wave accelerators. Many researchers--including Dr. J.D. Lawson in the Technology Division of RAL and a noted accelerator scientist--believe that the best and perhaps only chance of really achieving spectacular

accelerating fields is offered by the last type of device.

If two electromagnetic waves--specifically, two energetic laser beams with frequency ω and $\omega + \omega_0$ --are simultaneously directed into a plasma, then provided ω_0 is equal to the plasma frequency $\omega_p = (ne/m_e)^{1/2}$, a beat-wave will be generated which has a longitudinal electric field. (In the formula, n is the plasma density, e the particle charge, and m_e the rest mass.) This wave is a longitudinally polarized "Langmuir wave" which travels with a phase velocity that equals the group velocity of the individual transverse waves. The field arises from interference bunching and rarefaction of the particle density and has a limiting value when the rarefaction has reduced the local density to zero. The wave phase velocity is less than that of light by the very small fraction $1/2\omega_0^2$. It is interesting to note that the Langmuir wave is generated by the ponderomotive force on the plasma particles, which in turn is proportional to the gradient of the averaged square of the electric field strength. (The gradient comes from the beating of the two laser waves.) Overall, we have a second-order effect proportional to the square of the laser field. The Langmuir waves are nonlinear near the limiting amplitude (referred to above), and it can be shown that the maximum value of the longitudinal electric field is

$$E_{\text{max}} = \frac{1}{2} \frac{m_e c^2}{e \lambda} \left(\frac{\omega_0}{\omega} \right)^2,$$

where λ is the laser wavelength near unity. Thus, the accelerating longitudinal field in the plasma can be quite spectacular, even at low plasma densities. Unfortunately, the plasma density cannot be made too large because that implies a large value for ω_p/ω , so that the difference between the wave and light velocities becomes larger. To avoid the limiting effect of this, the accelerator should be broken down into stages or the three beams (two laser and one particle) should be made noncollinear.

The practicability of this exciting beat-wave laser accelerator scheme is not uncertain. In particular, a link must yet be found between the well-understood physical process and a credible scheme for a realizable device. It was with this anxiety-mixed enthusiasm that a powerful study group had been set up at FAL. A first report has already been published. It studied the possible parameters for a machine for approximately 1-TeV energy and looked carefully at problems such as how to produce the

plasma, what factors determine luminosity, and how to arrange for "staging." Other questions raised were: What can be assumed about the laser optics? For how long a pulse can the channel be sustained with resonant plasma? What are the power, pulse length, and repetition rate needed to satisfy basic design requirements? What is the effect of multiple scattering and plasma noise on the beam emittance? And so forth. So far there have been no satisfactory answers. Meanwhile, experiments are planned in the US to try setting up and detecting a beat wave. There was also a lot of enthusiasm expressed at an international accelerator conference at Frascati, Italy, at the end of last September.

There are now hopes that despite the gloomy tone of the FAL study group's first report, an experiment with beat waves will also be set up in the UK. But Lawson warns: If the accelerator community is to make progress, then it will be necessary that accelerator physicists acquire some understanding of plasma physics, and also that plasma physicists find out what is it that accelerator people need to know and what they are trying to do.

12/17/84

LASER RESEARCH AT IMPERIAL COLLEGE, LONDON

By Paul L. Lee.

While optics is probably one of the earliest explored subfields of physics, the last 25 years have led to a new golden age. The advent of quantum optics and quantum electronics opened up new vistas both in our basic understanding of phenomena and also in uncountable fields of applications. Indeed, lasers, for example, are now used in areas as diverse as military and weapons applications, communication, metrology, surgery, manufacturing technology, spectroscopy, and entertainment. These applications depend crucially on continuing front-line research. Nonlinear optical phenomena come more and more into focus as the means to make lasers "deliver" newer tasks. Problems like shortening laser pulses to 10^{-15} second durations or developing highly tunable lasers with sufficient energy output and efficiency for use in optical communication (based either on semiconductors or color-center-containing crystals) are frontier

ment, one of the most dynamic research centers in the UK--where precisely these rapidly developing frontier areas are vigorously attacked--is the Optics Section of the Physics Department at the Imperial College of London. A report on current and planned work at this institution should be of both practical and intellectual value to readers of *ESN*.

The Physics Department at the Imperial College of Science and Technology has no need introduction. Its high level of recognition is mirrored, among more tangible things, by the statistical data: currently one Nobel laureate and nine fellows of the Royal Society are in the ranks of its faculty.

This article can only highlight some selected research I learned about during a visit to the department's optics section. The section is headed by Professor R. New; it consists of about 40 people (staff faculty, 17 research associates) and enjoys external support from the Science and Engineering Research Council, the Ministry of Defence, and other industrial groups. The major research activities in various aspects of optics, with a heavy emphasis on laser development and improvement, fall into a theoretical division (Dr. J. H. E. Smith), which is interested in quantum optics, especially multiphoton processes, as well as computer modeling of lasers, particularly the aspects of laser pulse generation. The experimental division has two focal areas: the ultraviolet (UV) and vacuum ultraviolet (VUV) lasers, pulse generation, and phase conjugation experiments. The other is the generation and measurement of ultrashort pulses, and their pulse propagation studies in optical fibers, with an eye not only on optical communication but also possibly on optical computing. Some activities of the experimental group are surveyed below.

Narrow-Bandwidth Phenomena and Applications

Narrow-Bandwidth Tunable VUV Laser. Dr. H. E. Hutchinson and associates have developed and are currently perfecting a method for generating, with relatively high conversion efficiency, very narrow bandwidth and widely tunable coherent VUV radiation. The basic idea is frequency mixing. In the more usual situation with $\omega = \omega_1 + \omega_2 + \dots$, the requirement that the dispersion of the medium, $k = k_1 + k_2 + k_3 + \dots$, be negative (a tightly focused beam restricts the choice of the nonlinear medium and of the available tuning range. However, if one uses difference frequency mixing by the process $\omega = \omega_1 - \omega_2 = \dots$, then

k may be either positive or negative. This scheme was realized by Hutchinson for VUV generation by difference frequency mixing in xenon. The energy level diagram is illustrated in Figure 1. The susceptibility for four-wave mixing was enhanced by tuning to the $5p^2 S - 5p^2 P$ two-photon transition with $\lambda = 249.6$ nm. Continuously tunable radiation was obtained by mixing with tunable radiation from a second dye laser.

The complete experimental arrangement is sketched in Figure 2. A commercial discharge-pumped XeCl excimer ($\lambda = 308$ nm) was used to pump two narrow-bandwidth dye laser oscillators, each having a chain of amplifiers. One dye oscillator (with Coumarin 307) was tuned to 499 nm, and the other (with Rhodamine 101) was tunable between 610 and 650 nm. The oscillators used a grazing incidence grating for both dispersion and beam expansion (but the second laser also included a four-prism beam expander). The remaining 90 percent of the XeCl pump beam was used to pump two amplifiers in each arm of the dye laser system. The amplifications were $\times 80$ and $\times 8$, giving outputs of 2.5 mJ and 1.5 mJ, respectively. The pulse duration was 10 ns. Next, the 499-nm beam was focused into a potassium pentaborate frequency-doubling crystal. The second harmonic (generated with an efficiency of about 1 percent) was recollimated and passed through a KrF excimer amplifier, giving a single pass gain of about $\times 100$. (Proper synchronization between the pumping XeCl laser and the KrF amplifier was achieved using cleverly arranged thyatron switches.) With the use of a dielectric coated mirror, the amplified 249.6-nm beam and the 630-nm beam were combined and collimated. The combined

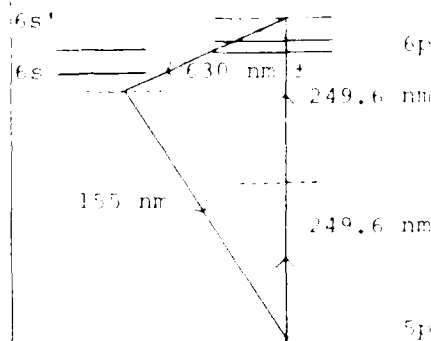


Figure 1. Energy level scheme.

and production capabilities have developed from a sound national research program focused on defense, scientific, economic and societal technology requirements.

Space Sciences

ESA'S FUTURE PROGRAM IN EARTH OBSERVATIONS

by James A. Lee. Dr. Lee is the Chief Scientist for Space Physics in the Office of the Chief of Staff for the Office of Naval Research's London Branch. He is on assignment until June 1986 from the Naval Space Flight Center, 441, where he is Chief, Laboratory for Space and Planetary Physics.

The European Space Agency (ESA) has just completed a study and published a report entitled *Looking Down, Looking Forward*, which presents a perspective on its future scientific and application program in Earth observations. This is an optional program within ESA, as distinct from the mandatory scientific program, whose future was discussed in ESN 39-4:169-173 (1985). The term optional means that member states can decide individually whether or not to participate.

Background

During the past 25 years, a new global perspective of man's environment has developed. As a result, a better understanding has emerged of the complex interactions which occur between the atmosphere, oceans, ice regions, and land surfaces. Already observations from polar orbiting and geostationary satellites such as ESA's METEOSAT are used routinely within Europe in developing operational meteorological forecasts which are useful for up to 5 or 6 days. Remote sensing techniques have been developed to observe the sea state and will be used on ESA's first remote sensing satellite, ERS 1, to be launched in 1989. Its data will be exploited for shipping, commerce, the offshore industry, and other applications. In addition, remote sensing of land over a broad electromagnetic-frequency spectrum is now used in many fields such as agri-

culture, forestry, geology, hydrology, land utilization, topography, and glaciology. Studies on a global scale of the structure and composition of the middle atmosphere have improved our understanding of the interplay between solar radiation, in-situ chemistry and dynamics, and, as a result, have enhanced the assessment of their influence on the critical ozone layer. Finally, precise and accurate tracking of satellite trajectories has improved our knowledge of the shape of the Earth, its gravitational field, and the relative motion of its land masses.

In all these areas, the potential for future development and exploitation of remote sensing observations from space is immense. The principal considerations which have gone into the ESA program for Earth observations are as follows: a strong scientific and industrial base exists in Europe in the high-tech and communication areas of optical, infrared, and microwave technology such as radar and lidar; a continuing need exists for future flight opportunities to test new instruments for remote sensing which may be developed by universities or research institutes (through funding by national sources); the program must be closely coordinated with existing and planned international activities in Earth observations; and a demonstrable requirement exists for routine monitoring on a global basis in order to study temporal variations of critical parameters.

As was done in the Horizon 2000 program document (ESN 39-4:169-173 [1985]), the ESA Earth-observation program is based on four cornerstone mission areas: (1) enhanced European participation in satellites for meteorological research, and in particular development of a second generation METEOSAT to be placed in geostationary orbit; (2) the establishment of a balanced program of research, development, and operations in ocean/ice observations following the first European Remote Sensing satellite mission, ERS 1; (3) a major mission for all-weather monitoring and optical observation of the land surfaces; and (4) a major mission which can exploit precise measurement techniques for solid-Earth geophysics.

It is also hoped to be able to conduct several flights of the retrievable EURECA platform, providing in-orbit testing of advanced instrumentation and launch opportunities for other areas such as middle atmosphere research, in which a dedicated ESA mission has not yet been developed. ESA considers it imperative that European mission plans be coordinated with other countries, such

industry which also manufactures the materiel, except for a small portion which may be procured from foreign sources. The FMV's research needs are largely met by the National Defence Research Institute, but FMV's role throughout the research and development cycle is to exercise qualified program management and direction. Of the total Swedish military defense expenditure for the 1983-84 fiscal year of over SKr10 billion, research and development costs amounted to nearly SKr2 billion or slightly less than 10 percent of the total defense budget. More than 90 percent of this R&D expenditure goes to industry, mainly in the form of development orders for special projects or equipment. In this way the Swedish defense authorities contribute to maintaining Sweden's high technological standards. The SKr1,921 million R&D expenditure in fiscal year 1983-84 is broken down as shown:

	Millions of SKr
Army	250
Navy	94
Air Force	1,251
Defence Authority	326
Total	1,921

The heavy emphasis on air force R&D expenditure is based on the full-scale engineering design and development effort being in 1984 on the JAS-39 fighter-multi-role combat aircraft. Five prototypes are under construction at Saab-Linköping in Linköping and will first fly in 1988. Without seriously impacting the JAS-39 development effort, however, the Swedish government plans to increase its defense spending in the area of anti-submarine warfare (ASW) based on Soviet intrusions into its territorial waters by "unidentified" submarines and nuclear missile vehicles. In his program for military defense for 1985-1990, the Swedish Supreme Commander General Ljung has asked the Swedish government for an additional SKr900 million for the purchase of underwater alarms, sonar systems, light ASW aircraft and equipment and proposed the procurement of several corvettes. General Ljung considers the ASW defense measures to be "extraordinarily urgent" and plans to transfer SKr100 million from the army budget to that of the navy, plus a similar sum from the air force budget, in order to pay for the upgrade of the ASW program.

Other Defense Research Activities

Several other centers of excellence in research are located in Sweden. With-

in the university academic structure, the Royal Institute of Technology in Stockholm is preeminent in the engineering and physical sciences for defense-related research. The University of Göteborg and the University of Lund are involved in high quality research in the human sciences and psychology for defense-related efforts in complex knowledge organization and training and testing analysis. The Uppsala University is strong in mathematics and computer science, as is the University of Linköping, where research in artificial intelligence as well as very high speed parallel processing has resulted in the development of high speed, high throughput computer processing hardware. In the areas of aerospace research, the Aeronautical Research Institute (FFA) in Bromma is the primary government aeronautical research organization. Additionally, the Chalmers Institute of Technology in Göteborg is strong in fluid mechanics.

Conclusion

If there is still question or doubt concerning Sweden's research and technology capabilities in the areas of defense and scientific endeavor, consider the high quality, high technology manufacturing output from this relatively small country of less than 10 million people. Saab and Volvo both manufacture high quality vehicles in large quantities that are exported all over the world. Ericsson and Philips are both highly regarded communications and electronics firms in the world marketplace. Bofors is well known for precision optics, electro-optics and electronic systems as well as for fire control, gun, and other weapons systems development and manufacture. Saab-Linköping is among the leading European aerospace companies capable of designing, developing, and manufacturing a wide range of well as high performance multi-role fighter aircraft. Volvo is known for its significant expertise in the production of materials and design of complete manufacturing equipment to produce major portions of the engine for the JAS-39 and JAS-37 aircraft. Volvo Flygmotor Space Industries is designing and developing high temperature combustion chambers for the Ariane space rocket engine for the European Space Agency. Sweden is among the world leaders in ferrous metallurgy and fabrication of high quality steel alloys. They are also highly regarded in nonferrous alloys and welding techniques. ASFA has become the European leader in robotics and automated manufacturing processes. Many of these high quality manufacturing

scientific disciplines of mathematics, chemistry, and physics and pursue research in the areas of explosives and fuels, projectiles and rockets, weapons launchers and platforms, propulsion and guidance, weapons effects to materials, and materials vulnerability and survivability, including protection by armor, camouflage, smoke, and obscurants. This department is the largest in FOA, employing over 400 persons in and around the Stockholm area. The department has additional responsibility associated with international development in nuclear weapons technology and thus gathers basic knowledge for design and evaluation of various nuclear weapons protective measures. The department also operates a seismological array station within the country.

The Applied Electronics Department, FOA-3, employs somewhat less than 400 personnel working in the areas of electronic and optical methods for collecting, processing, and interpreting information obtained by electromagnetic and acoustic wave propagation and detection. Military applications include communication, reconnaissance, guidance, and navigation systems as well as the countermeasures against such systems. The department is also involved in the study of effects and protection against the electromagnetic pulse (EMP) generated by nuclear explosions and the study of the effects of radiation on electronic components and systems. The department has several divisions, including information processing, optronics, communications, components and circuits, radar and action information, guidance and sensors, design and countermeasures, hydroacoustics, EMP protection and electromagnetic wave propagation.

The ABC Research Department, FOA-4, is mainly located in Umeå, which is about 750-km north of Stockholm. The department is involved in analysis of atomic, biological, and chemical warfare agents and their effects upon the human body. The effects of conventional weapons are also studied. This research effort involves personnel in the scientific disciplines of organic chemistry, biochemistry, toxicology and pharmacology, microbiology, radiobiology and radioecology, as well as applied physics. Studies in these fields result in basic knowledge which may be applied in the development of antidotes and of equipment for detection, protection, and decontamination. Knowledge gained by these studies, and by constant surveillance of international trends, is also used for technical assistance to Sweden's delegation at arms limitation conferences.

FOA-5 is the Human Studies Department, which has two of its divisions located in Karlstad, some 300-km west of Stockholm. It is planned by the mid-1980s that the remainder of the institute, which is now in Stockholm, will be relocated to Botkyrka, a Stockholm satellite community 20 km to the southwest. This department is involved in research on the human condition in war and on the man-machine interface. The personnel are mainly involved in medical and behavioral scientific research. The department is divided into units for army medicine, naval medicine, aviation medicine, behavioral sciences, biotechnology, and environmental technology. The ultimate aim of the research is to improve the conditions and functions of the human in the defense environment.

The Defence Materiel Administration

FMV also is directly subject to the direction and guidance of the Swedish government through the MOD, as shown in Figure 1; but in its daily routine, FMV follows directives and guidelines issued by the Supreme Commander of the Armed Forces, his Defence Staff, and the commanders-in-chief of the three military services. FMV's mission is to provide the national defense with the weapons and other defense supplies necessary for effective resistance against any well-equipped and well-trained enemy, and to see that this materiel is properly maintained and stored. The total value of defense materiel for which FMV is responsible exceeds SKr100 billion, and this equipment consists of more than one million different types of articles.

FMV is divided into six departments that employ over 3000 people, some of whom are military personnel. FMV is governed by a management board, and the director general of FMV is Mr. Carl-Olof Ternryd, who is chairman of the management board. The Central Management Department is charged with the overall direction of FMV's activities. Of the remaining five departments, three are mainly responsible for systems planning, materiel development, and maintenance tasks related to their respective service branches--the Army, Navy and Air Materiel Departments. Each is headed by a major general or rear admiral. The other two departments are the Commercial Activities Department, responsible for commercial and legal matters, and the Joint Support Activities Department, which is located in Karlstad and responsible for supply, workshop, and support services.

Defense materiel development, together with requisite research work, is primarily carried out by Swedish

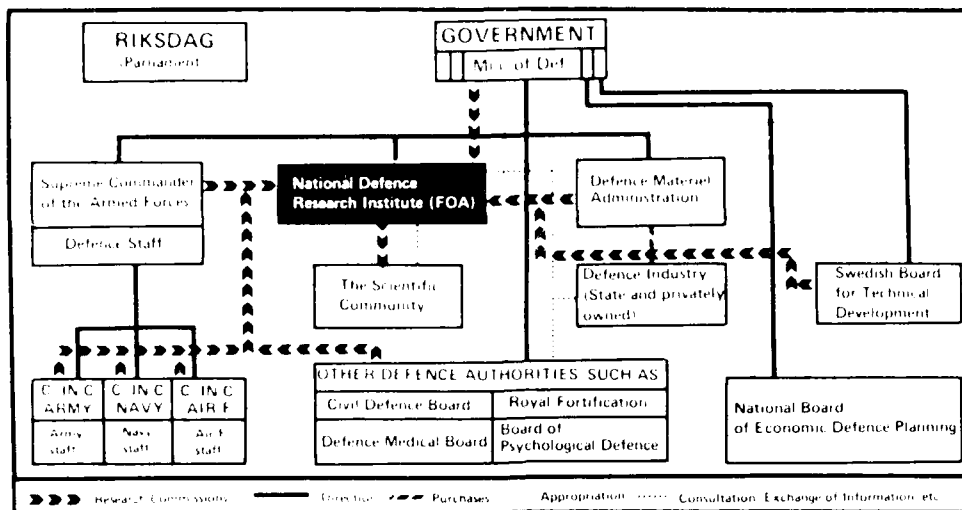


Figure 1. Overall defense organization in Sweden.

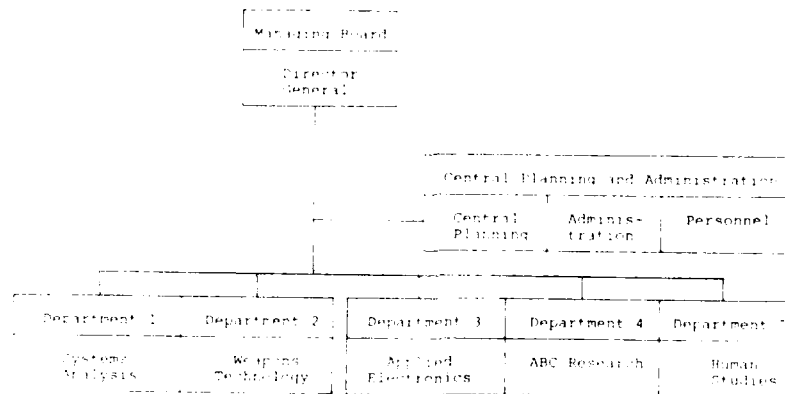


Figure 2. FOA organization.

of the departments have support units located outside Stockholm, and the entire FOA-3 Applied Electronics Department is located in Linköping, some 200-km south of Stockholm.

The Central Planning and Administration Unit assists the Managing Board and Director General of FOA, Dr. Lars-Erik Tammelin, who had previously been a research director within the organization. This Central Planning Staff Unit is responsible for research planning, financial and personnel planning, and administration. It also provides certain service functions to the various research departments, such as general accounting, legal assistance, internal education and training, and security.

FOA-1 is the Systems Analysis Department, employing some 125 personnel, whose main tasks are to conduct

independent studies, provide systems analysis on various research projects, and plan research activities. The actual projects range from studies on weapons systems to security policy and general development outlines for defense policy. The department is also responsible for the operations research and systems analysis organizations for the total defense effort and for recruiting and training its personnel. This department has a war-gaming laboratory and works closely with other operations research/systems analysis personnel at other national institutes and universities.

The Weapons Technology Department, FOA-2, conducts research on weapons and weapons systems, weapons effects and the protection against such effects. The research scientists cut across the

through the Skagerrak and Kattegat, Sweden is located in a strategically exposed position between the Soviet northern front and the NATO alliance nations on the northern flank of western Europe. In this geopolitical situation, Sweden maintains a strictly neutral, nonaligned posture in foreign policy, supported by a strong majority of the political parties and the people. Because of her avowed neutrality, Sweden cannot rely upon assistance from other countries for defense. The country must be prepared to defend against various types of aggression, which calls for a total defense system comprising the armed forces, civil defense, psychological defense, and economic defense. The total defense force must be strong enough to deter any potential aggressor and, should Sweden be attacked, to withstand the first onslaught, even if it is a surprise attack.

As a result of this alliance-free policy, Sweden must primarily rely on her own resources for the development of the various parts of this defense structure. Fortunately, Sweden is the leading industrial, economic, scientific, and military power in Scandinavia. This accounts for the expenditure of about 20 billion Swedish kronor (SKr), about \$2.2 billion, for defense, or about 7 percent of the total government budget in the 1983-84 fiscal year. This amount must be viewed against the background of the country's chosen foreign policy. Because Sweden's nonaligned posture precludes reliance on defense-system procurements from foreign nations, the government must fund and carry out extensive R&D efforts for defense within the country. Because of this, a sizable portion of the Swedish defense budget must be allocated to research, development, and procurement of defense materiel and weapons systems. The costs for such materiel run high due to the relatively small quantities procured or manufactured. Defense materiel accounts for about one-half of the total budget of the armed forces, and of this amount about 90 percent is spent on domestic production. The uncertainty and diversity of conditions under which Sweden's defense forces may be engaged necessitates planning for research and technological developments with both short-term and long-term objectives. A short-term objective is the development of new defense materiel and materiel processes. A long-term objective is forecasting the progress in technological fields that may become significant for military applications.

Swedish Defense Organization

To conduct this required planning and development strategy for procurement of military defense systems, the Swedish government, through the Ministry of Defence (MOD), relies on the Supreme Commander of the Armed Forces and his Defence Staff, the National Defence Research Institute (FOA), and the Defence Materiel Administration (FMV) to meet the country's defense requirements. This overall government organization is shown in Figure 1, which illustrates the interrelationships of the various agencies and major institutions involved in planning and executing Swedish defense policy. The Riksdag, as the supreme legislative body in Sweden, appropriates money for public expenditure, and thus exercises some control over development of national defense policy. FOA, like other defense organizations, reports directly to the MOD; however, the Supreme Commander has the right and responsibility on behalf of the total defense effort to assign priorities to the various research areas and studies being conducted by FOA. FOA is responsible for Swedish defense research, and the scope of the institute is accordingly very wide, covering disciplines such as chemistry, physics, medicine, mathematics, information technology, psychology, and social sciences. The primary purpose of FOA's work is to provide basic and applied research in support of the Swedish defense effort; however, many of the results of such basic and applied research benefit the civilian sectors of the society as well. As the chief agency of Swedish defense research, FOA also has the program-management responsibility for defense research produced by other agencies. Contrary to what is common in most other countries' defense organizations, however, FOA is not concerned with developing defense materiel. This generally comes under the purview of FMV, which has the responsibility for the development, testing, procurement, maintenance, and storage of military weapons systems and other defense materiel and supplies needed to equip the nation's defense forces. Each of these organizations and their associated defense research and development efforts will be described in more detail below.

The National Defence Research Institute

FOA is organized into five departments and a staff unit (Figure 2). The main FOA organization comprises some 1300 personnel in the staff and five departments. Most of the organization is located in Stockholm, although some

seems to have maintained its share of funding in the early 1980s after a steady decline during the 1970s. Despite this continued support, university R&D is stagnating. For example, the proportion of national R&D performed by higher education is falling in almost all countries for which comparable data are available.

The increase in US defense R&D spending (from 50 percent of total government R&D expenditures in 1980 to 70 percent in 1984) has not been mirrored in France, the UK, and most other countries with significant work in defense R&D. Even before the upturn, the US Department of Defense was by far the largest single R&D funding body in the OECD countries, spending the equivalent of the whole West German national R&D effort, or seven times as much as the largest individual firm. At the same time, private-sector R&D funding now exceeds total government military and nonmilitary R&D spending in the US.

On energy R&D, the US government cut federal spending to 5 percent of total government R&D in 1984 (12 percent in 1980)--largely by eliminating costly demonstration plants. There are signs that funding is leveling off elsewhere. Italy spends more than France or the UK on government support for energy R&D.

Industrial R&D

In almost all OECD countries, the amount of R&D financed by industry grew more rapidly than that funded by government. In addition, company-funded R&D continued to grow more rapidly in the early eighties than total industrial activities. Company funds represent more than two-thirds of all industrial R&D in almost all countries. The main exceptions are countries with big defense and aerospace programs.

In the early eighties, governments' contribution to industrial R&D picked up again after a decade of decline. In the US, this reflects the recovery in defense R&D programs, whereas in the other countries the funds are from programs to stimulate economic development.

The main feature of industrial R&D is its concentration in a few countries, with about 90 percent of the total performed by the US, Japan, West Germany, France, and the UK. Industrial R&D continues to be performed mainly in manufacturing industry and within manufacturing in the engineering and chemical industries (during the 1970s, the electronic and electrical industries overtook aerospace in spending on R&D).

The OECD report identifies another significant aspect of industrial R&D--the degree to which large companies,

many of them multinationals, determine the pace and direction of company-financed industrial R&D. Such companies are responsible for perhaps two-thirds of all industrial R&D. For example, General Motors in the US commits about as much money to R&D each year as industry in Italy or as government and industry combined in Sweden.

Ordering the Report

The OECD report is intended to set the scene for later reports that will evaluate the impact of R&D on society. The report is divided into five chapters; the first describes general trends in OECD countries, and the other four deal with OECD member countries grouped according to the size and structure of their national R&D efforts.

The report examines trends in the total amount of financial and human resources for R&D, the contribution of the public and private sectors to the financing of national R&D efforts, and the varying roles of industry and the universities. Public support for R&D is further analyzed in terms of socioeconomic objectives, with special attention being given to energy, health, and defense programs. The report also presents trends in R&D by the major industry groups--for example, engineering and electronics, chemicals, and aerospace.

To order the report, which costs \$27, write to: OECD Publications and Information Center, Suite 1207, 1750 Pennsylvania Avenue, NW, Washington, DC 20006-4582.

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SWEDISH DEFENSE POLICY AND R&D ACTIVITY

by CAPT L. Laddie Coburn, USN. CAPT Coburn is the Director of the Naval Applications Division and the Aerospace Systems Officer for military aerospace research and technology in Europe and the Middle East for the Office of Naval Research's London Branch Office.

Sweden, although relatively small in population with approximately 8.3 million people, is quite large in area and is geographically located in a critically strategic military position in the Scandinavian northern flank of western Europe. With her entire eastern shoreline on the Baltic Sea and her southern approaches flanking the only warm water entrance to the Baltic Sea

Science Policy

R&D SUPPORT INCREASING IN OECD COUNTRIES

by Larry S. Shaffer. Dr. Shaffer is Editor of *European Science Notes*.

Funding for research in some Western countries is recovering from a 10-year slump, according to a report published by the Organization for Economic Cooperation and Development (OECD).

The *Science and Technology Indicators--Resources Devoted to R&D* focuses on trends in the funding and structure of national R&D efforts during the 1970s and examines prospects for the 1980s. The report is concerned with R&D in OECD member countries; funding in countries such as the USSR and East Germany is not included.

National R&D Trends

A general recovery in R&D spending in the late seventies has continued into the eighties, according to the report. R&D has grown more rapidly than gross domestic product (GDP) in all major economies and most Nordic countries (Figure 1).

R&D is concentrated in a few large countries, with nearly half the overall effort performed in the US. The US, Japan, West Germany, France, and the UK account for about 85 percent of the total spending. The US, West Germany, the UK, Japan, Switzerland, and Sweden now devote the highest percentages of GDP to R&D.

R&D has grown quickly in Japan, averaging 8 percent growth a year at fixed prices during the 1970s and 10 percent a year during the early 1980s. Japan's share of all OECD R&D funding is about 17 percent, up from 10 percent in 1969.

The countries of the European Economic Community (EEC) are increasing R&D spending at only about 3 percent a year at fixed prices. The EEC countries spend about 30 percent of the OECD countries' total bill for R&D, but this share is now declining after some growth in the early 1970s.

In the US, total R&D expenditures fell in the early 1970s but then recovered strongly. Recently, the US has been increasing its R&D support by 5 percent a year. Still, the US share of all OECD R&D funding fell from 55 percent in 1969 to 46 percent in 1981, according to the OECD report.

Government Support

Although most OECD governments are trying to limit budget increases, R&D

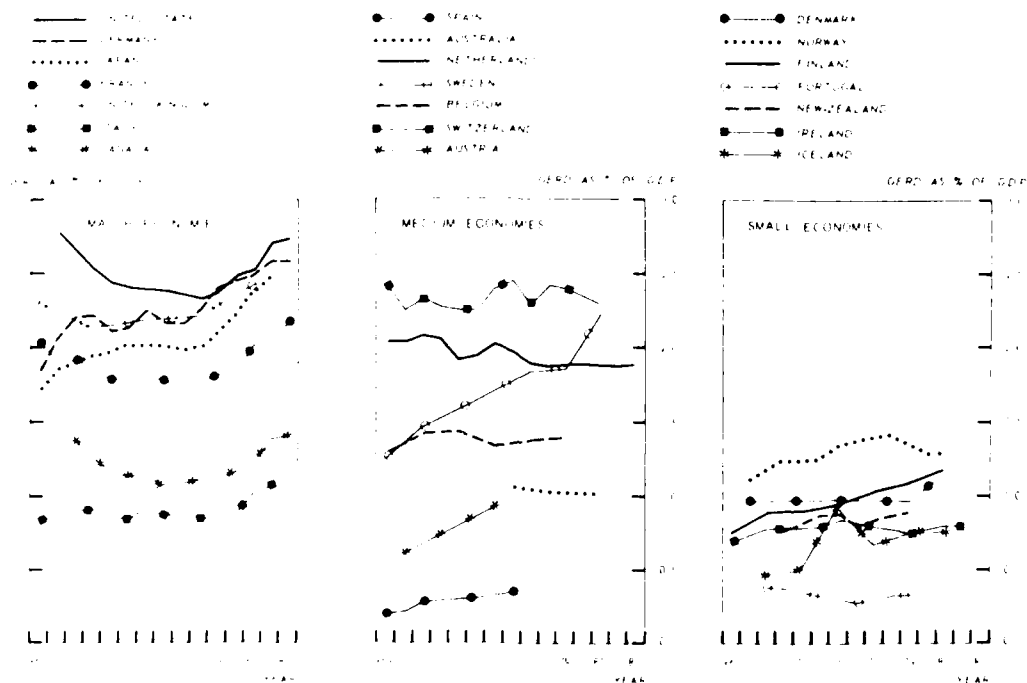


Figure 1. Gross domestic expenditure on R&D (GERD) as a percentage of GDP.

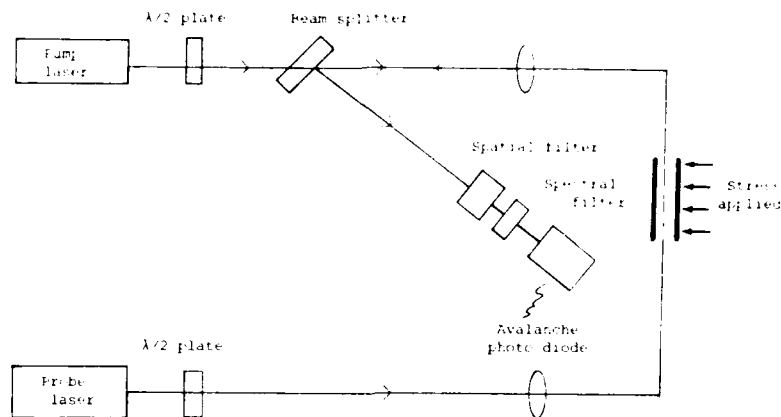


Figure 2. Experimental setup.

supported by JOERS falls into two main areas:

1. Investigation of the nonlinear optical properties of materials suitable for drawing into fibers on which distributed fiber sensors could be based.
2. Development of novel, high-speed, data acquisition and signal processing techniques suitable for use in distributed sensor applications.

In pursuing these goals, the department is expecting substantial cooperation with the Civil Engineering and Physics Departments of King's College. Close cooperation with the Central Electricity Research Laboratories (CERL) is envisaged.

One of the first pieces of research along the new lines of interest (M.C. Farries and A.J. Rogers, currently at CERL) is concerned with the development of a distributed optical-fiber stress sensor with a measurement path length of 25 m and a spatial resolution of 1 m. In principle, these figures can be extended to a path of several hundred meters and to a resolution of less than 0.1 m, the only limitation being given by the pump-laser pulse width and the response of the detection electronics. This unique sensor uses stimulated Raman interaction between counter-propagating pump and Stokes waves. A narrow pump pulse is launched into a monomode optical fiber. A counter-propagating continuous wave (probe) at the Stokes wavelength then experiences gain which depends on the relative polarization states of the two counter-propagations. The power level of the probe light emerging from the fiber is monitored as a function of time. Via

the Raman interaction, this function now provides information on the distribution of the polarization properties of the fiber. If these properties are influenced by an external agent to be measured (stress in the actual device, but it could be, for example, temperature, vibration, magnetic or electric field), then the measurand may be mapped along the length of the fiber. The output signal provides a real-time indication of the distribution of Raman gain with fiber location and does not need the processing required, for example, with a back-scatter technique.

In their experiments, the researchers obtained a power gain of 2.9 dB for a pump pulse of 48 mJ. (They note that due to pump absorption and forward Raman scattering the gain falls with distance from the pump input end.) The optical pump was a 9.5-ns pulse from a dye laser (pumped by a Nd:Yag laser) tuned to 617 nm. The probe beam came from a 5-mW, CW-operated HeNe laser at 632.8 nm. They used a low birefringence, "spun-preform" monomode fiber with both a primary and a secondary coating. Stress was applied by a manual vice.

Conclusion

This article focused on the two areas of research which put the department in the forefront of international efforts in two areas that are followed keenly in centers of US Navy research. Possibilities of cooperation are strong and desirable.

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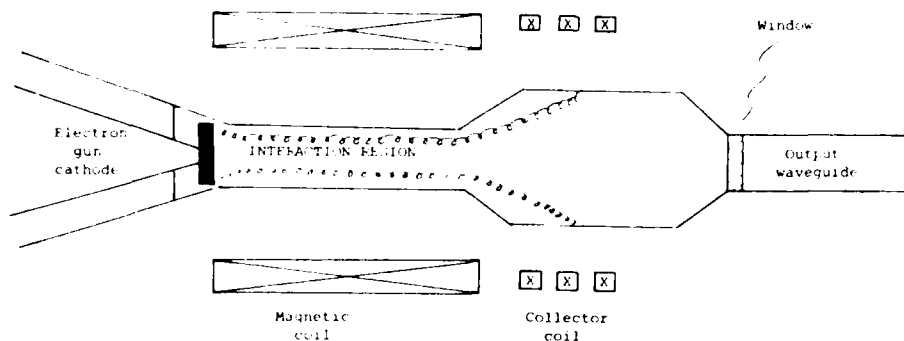


Figure 1. Operational scheme of a gyrotron.

scale were so much ahead of theoretical understanding that confidence in the practical development waned considerably, since by theory "the thing just couldn't really work." Consequently, when the financial crunch hit the universities, work was dropped--except in the USSR where, either because of inertia or foresight, intensive studies were continued. These eventually led to a partial understanding of the mechanism. In fact, it turned out that subtle relativistic effects play a major role. If these are properly taken into account, efficient performance can be predicted with confidence. As a result of these achievements, Western work started again to flourish. In particular, Lindsay and his coworkers first developed a theory of gyrotron amplifiers based on strictly microwave concepts, whereas earlier theories were largely based on the concept of plasma instabilities. As far as gyrotron oscillators are concerned, special emphasis was placed in these studies on the generation of spurious modes of oscillations.

Lindsay's gyrotron research is supported by the UK's Science and Engineering Research Council as well as by industrial companies and is conducted in close cooperation with the national Culham Laboratory. In his most recent work, he and his associates, Drs. R.M. Jones and R.J. Lumsden, achieved a clear and compact model of the gyrotron interaction mechanism, based on the concept of filamentary and tubular "beamlets" and their interaction with a waveguide or cavity electromagnetic field. Contrary to currently accepted views, Lindsay shows that five different energy-transfer mechanisms are operative, three of them acting in the transverse and two in the axial direction. In particular, one mechanism is due to the relativistic variation of the electron mass, and the

other is due to the magnetic component of the radio-frequency field (also a relativistic effect). He also shows that when a gyrotron is operating near the cutoff frequency of a TE mode, then effects due to the relativistic variation of the electron mass predominate, and the amplification process is at its maximum.

Even though, as noted above, the importance of relativistic effects has been known for some time, Lindsay's complex picture is quite revolutionary and needs definitive experimental confirmation. As one important test, he suggests the study of gyrotron amplification as a function of the transit angle.

Optical Fibers and Sensors

These topics were for quite a while high-priority areas in Lindsay's group, and originated from extending research in modern optics. A particular line of research, followed by Lindsay in conjunction with Dr. A.J. Rogers and Mr. M. Farries, concerned the development of distributed sensing techniques. This rapidly growing area of research, with many practical applications, allows the determination of the spatial variation of a given entity along the length of an optical fiber. For example, the measurement of electric and magnetic fields, stress, strain, and temperature in large structures (ships, bridges, power lines) or in hostile environments calls for these approaches. One interesting, typical basic-research result in this area was published by the group last year; it was demonstrated that the electro-optic Kerr effect is potentially useful in optical measurement sensors. Low voltages can be used and electrostriction effects can be avoided.

Recently the department received a substantial development grant from the government's Joint Opto-Electronics Research Scheme (JOERS). The program to be

at 15.5 degrees from the crystal axis. The diode is mounted onto a copper heat sink. Because of the Brewster angling, the laser diode was put into a condition of frustrated feedback and was transformed into a gain medium only, so that no evidence of lasing was observed, even under the extreme condition of injection-currents 2.5 times the threshold current for zero-degree laser diodes.

The diode device was put into a resonator configuration so that one of its facets was at the center of a 5-cm radius of curvature semispherical mirror. This led to obtaining maximum feedback. A 20-magnification microscope objective collimated the laser diode emission from the other facet. A broadband dielectric mirror was used as the output coupler (in later arrangements, $\times 40$ magnification microscope objectives were optically coupled to both facets of the diode). A Fabry-Perot was inserted in the cavity to limit the laser spectral width (in another arrangement, the mirror and the F-P etalon were replaced by a diffraction grating).

In a series of already completed experiments, peak power of over 0.5 W has been observed with no evidence of any temporal or spectral substructure. Pulse durations in the neighborhood of 9.5 ps were observed, and tunability over more than 15 nm was confirmed.

The group expects further, probably spectacular progress in performance of this unique mode-locked laser system.

1984/7/4

NEW DIRECTIONS AT AN OLD DEPARTMENT: GYROTRON AND FIBER SENSOR RESEARCH AT KING'S COLLEGE

by Paul Eoman.

The Electronic and Electrical Engineering Department at King's College, London is rapidly moving into the forefront of research in gyrotron theory and fiber sensors. This increased activity has been encouraged by renewed support by the UK government.

Science and engineering have from a very early stage occupied a prominent position in the college: indeed its academic engineering school is probably the oldest in England, dating back to 1838. Giants like Charles Wheatstone, James Clerk Maxwell, and Sir William Siemens were associated with this school, and the latter made an endowment which, to

this day, supports the chair assigned to the head of the Electronic and Electrical Engineering Department. The incumbent is Professor C.W. Turner, a noted scientist and educator, who, among other degrees, holds a PhD from Stanford.

The department is a somewhat small but well-integrated unit, with strong interdisciplinary links to other engineering and science departments. There is a staff of about 20 people, and the undergraduate student body numbers over 250. In addition, there are well over 60 graduate and research students.

For convenience, the research done at the department is divided into three main categories: (1) devices and modeling, (2) sensing systems/devices, and (3) microprocessors and microelectronics.

The senior professor, and holder of a personal chair in physical electronics, is Dr. P.A. Lindsay, known to many US scientists both from international conferences and from his past extended work in the US. I recently discussed with him two unrelated major thrusts of research under his direction; these fall in the first two research categories listed above. The work concerns theoretical gyrotron research and the use of optical fibers as sensors. Both are currently hotly pursued topics worldwide.

Gyrotron Studies

Gyrotrons, also called cyclotron resonance masers, are novel and very promising members of the family of advanced microwave generators. Their operation is based on the cyclotron resonance coupling between microwave fields and an electron beam in vacuum. The operational scheme of a gyrotron is sketched in Figure 1. Note that this is a cross section, so that the entire electron beam is really a hollow beam with all electrons having helical motion.

Gyrotrons currently can produce electromagnetic radiation in the range of 20 to 1000 GHz, with peak power outputs from 1 MW to over 100 MW, and thus are greatly superior to conventional microwave tubes in regard to power output at very short wavelengths. Gyrotrons have a great potential for applications in millimeter-wave radar and communication systems, energy-beam weapons, and microwave heating of magnetically confined plasmas.

Gyrotron research has a curious history. Work started about 20 years ago, with King's College's electrical engineering department in the forefront, together with US and Soviet research. At one point, preliminary experimental work and actual wave generation on a small

source of hypershort pulses was a passively mode-locked ring CW dye laser (with Rh 6G) in which an intracavity dielectric tuning wedge provided limited tunability. At an operating wavelength of 617 nm they managed to get pulse durations of 200 fs. The laser pulses (100-W peak power, 83-MHz rep. rate) were amplified to 2-GW peak power in a four-stage dye amplifier pumped by the second harmonic of a Q-switched Nd:Yag laser. The amplified output was focused into a narrow bore capillary (0.2 or 0.75 mm) accurately located along the axis of a 1-m-long Raman cell. Initially they used hydrogen as the Raman medium. Two-photon fluorescence measurements of the duration of the amplified laser pulses after transmission through the waveguide without any Raman medium and of the first Stokes pulses indicated that the latter were shortened by factors between 2.5 and 2.9. In later experiments the researchers used methane for the Raman medium. Because of the very short phonon lifetime the enhanced gain now enables the first, second, and even third Stokes orders to be observed (at 152, 964, 1340 nm, respectively). For the first- and second-order gains, a shortening factor of 1.7 was found, corresponding to 150-fs duration. It was also established that these were transform limited durations. Even if no further pulse shortening is assumed in the third-order Stokes output, the peak powers at 1.34 μ m still exceed 5 MW. With these pioneering advances it became possible for the researchers at Imperial College to carry out time domain studies on a femtosecond scale in the near infrared: research possibly crucial for optical telecommunication.

Color-Center Lasers. Once ultra-short pulse reduction techniques were mastered, it became of paramount interest to search for appropriate lasers both to feed experimental devices exploring fiber transmission of bandwidth limited pulses (digital data transmission) and, ultimately, to be light sources for optical communication.

Color-center lasers are attracting increasing interest as very efficient sources of easily tunable, optically pumped sources of coherent radiation in the visible and in the near infrared. However, maintaining of the orientation of the color centers requires cooling of the active medium to cryogenic temperatures. This may be an annoying restriction for the operation of CW laser systems, but it also was demonstrated a few years ago that pulsed laser action could be achieved at room temperature. Sibbett's photonics group recently achieved tunable room-temperature laser operation

at two spectral bands (near and near infrared) from color centers in a slab of a LiF crystal pumped by the frequency-doubled output of a Q-switched Nd:Yag laser. The researchers observed an initial banding of laser action in the 215-nm area which was followed, however, by a period during which the intensity of the red emission reached a peak; as it decreased, a laser appeared in the 640-nm range (in fact, the latter at this infrared emission appeared in almost constant value and laser-stable operation could be maintained).

The active material was a 10x10x5-mm slab of LiF irradiated with γ -rays. The pumping source produced 15-ns pulses at 1.0 μ m wavelength with 80-mJ energy at 10-Hz rep. rate. This light was focused by a cylindrical lens onto the 10-mm face in a transverse pumping geometry.

The results summarized above have encouraged the group to search for more stable and versatile alkali-halide tunable nanosecond laser sources at longer wavelengths, which could operate stably in a pulsed mode, at room temperature.

Mode-Locked Semiconductor Lasers. Another, and more traditional, although less tunable, source for experimentation (and ultimate commercial use) in optical communication is the class of semiconductor diode lasers. These provide a variety of means for compositional tuning, and for a selected composition limited temperature tuning can be employed. However, these lasers do not possess sufficient phase coherence for use in very-high-performance, coherent, optical communication systems, and when operated with RF injection currents, they do not produce sufficiently short pulses for use at ultra-high bit rates. To achieve sufficiently high bit rates, picosecond optical pulses must be produced in a mode-locked configuration. This suggested to the researchers the use of a semiconductor laser coupled to an external oscillator. However, reflection from the diode facets (even if they are antireflection coated) causes diode mode structure and so introduces additional temporal structure on the mode-locked pulses.

Not long ago Drs. Sibbett, J.I. Vukusic, J. Chen (now back at Sichuan University, People's Republic of China) and coworkers came up with the pioneering idea to use oxide insulated GaAlAs stripe geometry diodes, where the stripe was tilted at an angle from the crystal axis which is nearly equal to the Brewster angle for GaAs. In this way, they achieved a unique solution for near-perfect mode locking. Their 500- μ m-long diodes have a 15- μ m-wide stripe tilted

also reduce the Brillouin gain--even though they produce significantly shorter durations. In summary, it seems that the use of a B-cavity could provide a useful technique for producing short-duration pulses of high intensity from laser systems where more conventional methods are not convenient, allowing high beam quality at the same time.

Current plans include the synchronization of the length of the pump cavity to that of the B-cavity. Furthermore, experiments are under way to optimize the degree of phase-conjugate fidelity (which, incidentally, is less in SBS-based methods than in four-wave mixing techniques). A new approach using heterodyning to measure the phase-conjugate fraction of the reflected signal will be published soon.

Miscellaneous Plans. The nonlinear effects researchers also have a few other plans which I can mention but briefly. One is to develop distributed-feedback dye laser systems which, they think, will produce (because of the smallness of the volume) nanosecond-to-picosecond compression in a simple device, allowing also for great tunability. In addition, frequency doubling and reinjection into an excimer may then lead to very strong and very short VUV pulses.

Another, more technical, research line aims at increasing from the usual 1 percent to 3 percent the efficiency of x-ray preionized excimer lasers, by means of a backcoupling mechanism that leads to optimal operating conditions.

Ultrashort Pulses

Dr. W. Sibbett, who showed me around the labs where these efforts are concentrated, explained that their work concerns, foremost, generation of ultrashort laser pulses (i.e., construction of highly specialized laser systems); second, measurement techniques, devices, and actual measurements adapted to such time scales; and third, exploration and application of phenomena on this time scale. Their research is supported in part by British Telecom and by Phillips, because the current emphasis of the work is on the physical basis of optical telecommunication. This involves study of both solid state systems such as color-center lasers as well as semiconductor research in the area of diode lasers. Getting ultrashort pulses in different ways, studying the propagation of such pulses in fibers, and developing instrumentation (such as streak cameras) are all topics that have both basic and applied research aspects. Some of the recent accomplishments are described below.

Mode-Locked Ring CW Dye Lasers.

Several years ago, passive mode locking of continuous wave (CW) dye lasers was established as a reliable means for generating ultrashort light pulses. Sibbett's group used a particular version of previously suggested arrangements to make careful studies of both pulse width and interpulse jitter. They built a ring CW dye laser, where a solution of Rhodamine 6G was pumped by the 514.5-nm line from an argon ion laser with 3- to 6-W output. The saturable absorber was a solution of DODCl in a free-flowing jet stream of about 100- μ m thickness. The output beams were taken through a mirror and frequency tuned by an intracavity dielectric tuning wedge. The average power in each beam was near 10 mW. The cavity transit time was approximately 12 ns, corresponding to a pulse repetition frequency of 83 MHz. For the measurement of pulse width, one of the beams was directed to an autocorrelator with a second harmonic generation crystal, and the other beam was subdivided to provide a trigger signal to the radio-frequency (RF) circuitry; the remainder illuminated the input slit of a synchroscan camera used to determine the long-term jitter. It was found that single pulse operation could be maintained for pump powers only 50 to 70 percent above threshold and that pulse durations decreased rapidly with increasing pump power (and then stabilized). Pulses not longer than 0.18 ps have been observed (using pump power just over 45 W only). In summary, the advanced streak results demonstrated that both the laser-pulse duration and the jitter (accumulated during the approximately 1-second-long recording period) are substantially less than 1 ps. The low value of the jitter (accumulated during 10^8 cavity periods!) is attributed to the mechanism of the colliding pulse mode locking because the propagating pulses experience minimal loss in the saturable absorber when the difference in arrival time is zero. The authors add that this may be complemented by a transient-absorption grating which would tend to couple together the counter-propagating pulses and therefore enhance the precision of the synchronization.

In their further push for shorter and shorter pulses, the research group experimented also with transient stimulated Raman scattering of femtosecond laser pulses. They based their work on the fact that stimulated Raman scattering of mode-locked CW dye laser pulses provides a convenient mechanism for the production of frequency-tunable femtosecond pulses in the entire region from ultraviolet to near infrared. Their

second-order Stokes radiation is not a serious problem since SRS is only in the backward direction. In addition, the quantum efficiency of SRS is almost 100 percent since the Stokes frequency is approximately equal to the laser frequency, and therefore the Stokes pulse may be further amplified in a laser amplifier. Also, since the Brillouin process is initiated spontaneously in the medium, there is no need for an injected Stokes pulse. The system is remarkably simple: it only needs a tube filled with an appropriate liquid in which the large acoustic wave is driven. One other exciting characteristic of SRS is that under appropriate conditions the Stokes wave is a phase conjugate of the input wave. (Pioneering work in this area was done first by Soviet authors.) Apart from other uses of phase conjugation, this allows for compensation of optical inhomogeneities in laser amplifiers. One price to pay for all these fine features of SRS applications is that there is a threshold below which no scattering occurs.

After earlier experiments with different arrangements that demonstrated the efficiency and versatility of the Brillouin mirror for pulse compression, Damzen and Hutchinson recently concentrated their efforts on achieving pulse compression in a phase-conjugating Brillouin cavity. Phase conjugate signals are usually produced by degenerate four wave mixing (see also ESN 39-3:101-104 [1985]), but the Imperial College scientists assert that the use of SRS provides a more efficient and convenient phase-conjugating mirror.

High reflectivities can be achieved without the need for the strong pumping beams (or other exciting mechanisms) of the four-wave mixing process. The tricky requirement of critical alignment and good-quality pump beams is thereby eliminated. Furthermore, in addition to controlling the transverse features of the pulse by phase conjugation, the Brillouin mirror can tailor the time profile of

the pulse--if one uses suitable interaction geometry, and if one carefully adjusts the transient and nonlinear characteristics of the process. With these points in mind, the authors built a cavity formed by a pair of Brillouin mirrors, taking advantage of both the phase-conjugating and pulse-compressing mechanisms of the SRS process. In this manner, a phase-conjugate resonator was produced which emits a train of intense pulses of subnanosecond duration.

The setup is sketched in Figure 3. The output pulse of a Q-switched ruby laser was amplified to about 100-mJ pulse energy. The radiation was focused into a 157-cm-long chamber containing methane at 80 atm pressure, and a second focus was formed by a second lens inside the chamber. The two focal regions act as Brillouin mirrors, so that a cavity (the "B-cavity") was produced which was capable of oscillation. The purpose of the ruby oscillator in the entire laser system, which consists of the B-cavity coupled to the pump cavity, is simply to inject the input narrow-line-width pulse so as to reach the threshold for SRS and to initiate the oscillations. It does not play a role in the subsequent dynamics since its gain is depleted when the reflected Brillouin pulses return. (But its output mirror serves as a resonator mirror for the ruby amplifier.)

The output of the system was monitored by a photodiode that obtained illumination from a beam splitter placed between the ruby amplifier and the entrance lens. Broad pulse structures up to 50-ns duration were seen when 40-ns-long input pulses were used. The shortest pulses seen in the train were 300-ps long. The researchers say that if narrow-bandwidth pressurized XeCl or KrF lasers are used, pulses as short as 100 ps could be produced by pulse compression. Even shorter pulses are expected with transparent Brillouin active liquids for which the acoustic frequency is relatively large. In this case, transient interactions may occur which

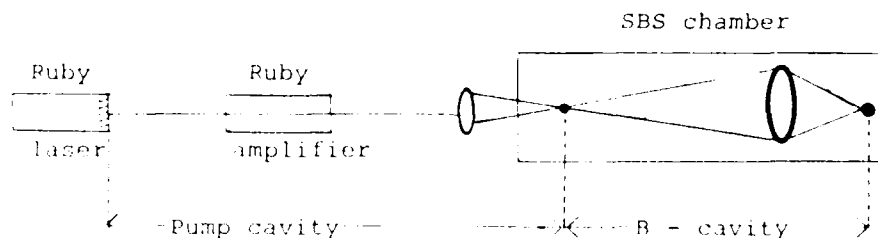


Figure 3. Phase-conjugate resonator.

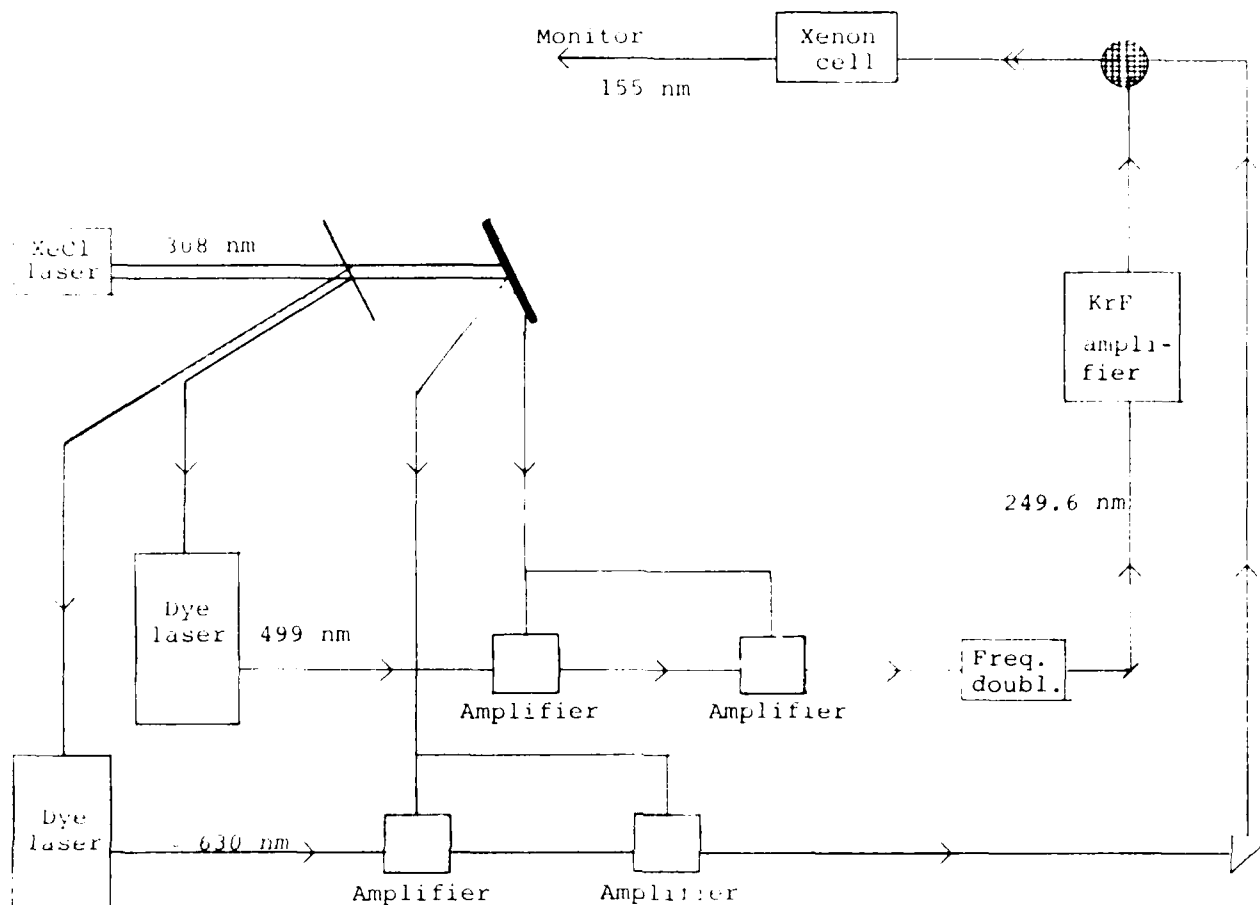


Figure 2. Experimental setup.

beam was then focused into the center of an 8-cm-long xenon cell mounted on the front of a commercial VUV monochromator. This is the place where the process $\omega_{\text{VUV}} = 2\omega_{\text{UV}} - \omega_{\text{vis}}$ took place. The UV pulse at 249.6 nm had 30-kW power; the visible 630-nm pulse had 25 kW. The resulting 155-nm VUV radiation had up to 100-W peak power and was produced in about 5-ns pulses. The tuning of the VUV radiation was achieved, of course, by tuning the 630-nm dye laser. The VUV radiation was detected by a photomultiplier, and the signals were processed by a standard transient digitizer and minicomputer.

In summary, the experiments so far have demonstrated that two-photon resonantly enhanced four-wave frequency mixing in xenon offers a good method of producing continuously tunable, very-narrow-bandwidth (near 1 GHz) VUV radiation of relatively high power and a wide spectral range, with an efficiency near to 0.25 percent. On the other hand, saturation effects were observed, leading

to some spectral broadening. Current experiments are therefore being conducted to investigate these effects by means of a detailed study of the ionization process (rates) in the ionization chamber. Other experiments are under way to develop an automatic computer control of the entire system. Finally, tuning between modes will be also investigated.

Brillouin Scattering and Applications. Since the early 1980s, there has been considerable interest in the production of pulse compression by backward-wave amplification. There are two popular routes: via stimulated Raman scattering or, more recently, by means of stimulated Brillouin scattering (SBS). The Imperial College group, especially Drs. M.H.R. Hutchinson and M.J. Damzen, strongly advocate the latter. They have demonstrated not only that it can be done easily, but also that it has many advantages, such as permitting considerably higher efficiencies at higher compression ratios. This is so because the production of

as the US and Japan, and anticipates participation in the polar platform component of the future US space station.

Achievements in Earth Observations

Substantial achievements have been made in observing the Earth from space. Coupled with very rapid developments in computer technology, such satellite observations have had a major impact on the research and operational field of meteorology. The international Global Atmospheric Research Program (GARP) was established jointly by the World Meteorological Organization and International Council of Scientific Unions. Its main objective was an understanding of the basic physical and dynamical processes of the global atmosphere, and its ultimate goal was to improve medium- and extended-range weather forecasting. GARP culminated with the Global Weather Experiment in 1979. Five geostationary spacecraft of the US, Japan, ESA, and the USSR along with two polar orbiting satellites of the US and USSR, as well as drifting buoys and balloons and aircraft, provided continuous observations. The European Center for Medium Range Weather Forecasting (located in Reading, UK) was responsible for analyzing the data of the year-long experiment. ESA's contribution was METEOSAT, and it is that spacecraft which now provides routine images that are used by most European weather services for short-range forecasting. The US spacecraft, Nimbus-7, included a number of instruments to provide global measurements of the structure and composition of the middle atmosphere for the first time. Two of these, the selective chopper radiometer and the passive modulation radiometer, were provided by European laboratories.

Since more than 70 percent of the Earth's ocean is covered by water or ice, an understanding of the ocean-ice distribution and interfaces with the atmosphere are essential for climatic studies as well as exploitation of resources in and beneath the oceans. In contrast to the transparencies of the atmosphere, the interior of the oceans is impenetrable by remote sensing. Detailed measurements of the sea-surface/atmosphere interface are critical to provide information on subsurface structure and dynamics. Although ESA has not been involved directly in the spacecraft mission SEASAT, which provides critical data for these studies, it has participated in the exploitation of these data with the development of analysis and interpretation methods. Several users groups have been formed within Europe to accomplish this. In particular, a specific effort to use the synthetic

aperture radar data set from SEASAT was undertaken jointly by the ESA and the European Economic Community in their SAR580 campaign.

For the remaining 30 percent of the Earth's surface, which is land-covered, effective management of resources is the main challenge of the future. Spectral reflectance measurements in the visible and near-infrared portion of the electromagnetic spectrum and radiometric measurements in the thermal infrared and microwave portion of the spectrum have been made of the land surfaces. A metric camera experiment provided by West Germany for flight on Spacelab 1 demonstrated the ability to obtain high-resolution digital data from space. The ability of the Shuttle Imaging Radar to penetrate cloud cover has provided weather-independent daytime and nighttime observations, as done by SEASAT.

Analysis of the spectral signature of the back-scattered energy can provide useful data on the chemical composition and microscopic structure of the land surface and its vegetative cover. However, such spectral signatures can be affected by both atmospheric conditions as well as the illumination angle, so further research in the interpretive area is critical. It is expected that application of such land observations will benefit both renewable and nonrenewable resources, the environment, and finally hydrographic and land-use planning.

Solid-Earth physics has benefited primarily through the careful application of geodetic techniques directed toward studies of plate motion, Earth rotation, the Earth's gravity field and its geoid, the Earth's magnetic field and its secular change, and finally the dissemination of accurate time. These separate areas are, in fact, very closely intertwined since use is made of satellite trajectories. Thus, future research in these areas will depend on parallel advances in each area.

The last area in which significant accomplishments have been made relate to climate and environment. The question of man's impact on his environment is no longer unanswerable. It is demonstrably clear that there is now a critical need to properly assess the adverse impact which economic development and industrialization have had and will have on the environment. In addition, spacecraft observations have provided useful data to understand naturally occurring events--for example the extreme El Niño event of 1982-83, which was responsible for anomalous weather patterns throughout the world. A critical question has arisen in connection with the increase in the

concentration of CO₂ in the atmosphere due to burning of fossil fuel and deforestation. There are predictions that the mean global temperature may rise by as much as 2 or 3 degrees during the next 50 years, which is a warming comparable in magnitude to the change from the last ice age to our present climate. But such predictions of both magnitude and rate of change are not yet fully reliable and are difficult to determine because of the naturally occurring variability of the Earth's climate. The only answer to these important questions is careful and continuous monitoring of all climatic variables such as mean sea level, height of ice caps, atmospheric composition, and so on.

The European Program

During the last 20 years, European industry has developed its space capabilities considerably. With respect to Earth observations, it has developed a METEOSAT satellite with a sophisticated optical payload, the SIRIO and MARECS communications satellites, with a precise-time-dissemination payload LASSO, and the STARLETTE geodetic satellite. France is developing the SPOT satellite with an advanced optical payload, and ESA is developing the ERS 1 satellite with its advanced microwave payload. In addition, individual instruments or subsystems have been developed for flight on a number of US missions.

Since the Earth sciences require continuity of observation and permanent monitoring of the entire globe, polar orbiting or geostationary spacecraft are essential. Moreover, a multisensor and a multidisciplinary approach are both necessary. All the proposed missions in the future programs also require ground truth or *in-situ* measurements by rockets to calibrate or complement these remote sensing observations from space. There is a pressing need for both substantial international cooperation as well as strong national programs within member states to complement the ESA program.

In the first of the proposed program's cornerstone areas, atmospheres, ESA has recently decided to invest in three additional operational METEOSAT satellites to be launched in 1987, 1988, and 1990. This is expected to extend the European METEOSAT's service to the various meteorological offices and research institutions until 1995. Operation of these satellites in Europe will be a responsibility of the EUMETSAT organization. The principal task for ESA will be the development of a second generation METEOSAT utilizing more advanced instrumentation.

In the second cornerstone area, ESA has a near-term future mission, FRS 1, a European satellite for observing the oceans and ice under all weather conditions. It is scheduled for launch in 1989. In the future not only must these observations be continued, but an improved means must be developed for flight in a follow-up mission, FRS 2, to be launched in approximately 1992. The exploitation of the ocean and ice observations could become a responsibility of the same organization, EUMETSAT.

The third cornerstone area--optical and all-weather land observation--began with the successful shuttle-SPACELAB flight of the Modular Optoelectronic Multispectral Scanner of West Germany and will continue into the operational SPOT program of France, to be launched in 1985. A future high-priority mission representing this area is that of a Synthetic Aperture Radar, which should be launched in 1994--1995 at the latest.

The last area of interest for remote observations is that of the solid Earth. Here ESA plans the development of a precise point-positioning geodetic satellite for Earth dynamics research (POPSAT). While some of this payload could be accommodated by EURECA, an early flight opportunity on a shared launch with ERS 2 in 1996 is considered ideal.

The above key measures will be augmented by Flights of Opportunity on US platforms such as those of the National Oceanographic and Atmospheric Administration or the National Aeronautics and Space Administration. Since the investment of the ESA member states in the ERS 1 mission will peak in 1986-87, the new missions can only be considered for launch in the decade of the 1990s. However, there is a critical need for the scientific-technical community to be properly prepared in advance. The launch program is based on use of the expendable launch vehicle, ARIANE. It is expected that the program can be oriented later toward use of the polar platform element of the forthcoming space-station program. However, several critical questions need to be satisfactorily resolved before it can be shown that this is cost effective. Among these are automatic versus manned servicing, frequency of servicing, and rendezvous concepts.

The proposed ESA program is felt to be both balanced and integrated and to address the many different requirements in the various Earth-observation fields of remote sensing. This helps to provide a good balance between science and applications. The proposed program requires a budgetary level of 220 million

accounting units (MAU) by the end of the decade (one AU = \$0.81). For comparison, the mandatory science program budget will reach only 160 MAU by the same time.

The advisory committee for the Earth-observation program was chaired by J.P. Houghton of the UK. The individual working groups and their chairmen were: Land Applications (J. Rodechtel), Ocean Color (R. Frassetto), Solid Earth (P. Pacquet), and Atmosphere (L. Bengtsson). Copies of the report *Looking Back, Looking Forward* (ESA SP-1073, January 1985) can be obtained from ESA, 6-10 rue Mario Nikis, 75738 Paris CEDEX 15, France.

8/17/85

News and Notes

ACOUSTIC RADIATION IMPEDANCE STUDIES AT IMPERIAL COLLEGE

Professor Frank Leppington and Visiting Professor Harold Levine (Physics Department, Imperial College, London) have recent results on acoustic radiation efficiency and added mass for asymptotically large values of nondimensional wave number. I recently discussed with them theoretical work on the calculation of acoustic radiation efficiency and added mass of modes of a vibrating panel installed in an infinite baffle.

Levine has published asymptotic formulas for radiation efficiency of simply supported panel modes at high reduced wave numbers (Levine, 1984). It is significant that he worked in the spatial domain rather than in the wave-number domain. This simplified some quadratures. Leppington has also established similar results in unpublished work. It is of particular interest that for large mode numbers, he has found the radiation efficiencies at high values of ka greatly exceed unity. Here k is the acoustic wave number and a is the effective diameter of the panel. The terms are of order $\log ka$. Leppington's results were in apparent contradiction to my theoretical and experimental results regarding the mass law for a finite panel (Leehey, 1982). After considerable discussion we determined, however, that the matter related specifically to the evaluation of the radiation efficiencies of the nonresonant modes participating in the response of the

panel. In my case the excitation was by a normally incident plane wave, and this response therefore dominated by the very lowest modes of the panel. However, had a point excitation been used, it is quite likely that a higher mode, one for which the $\log ka$ behavior was important, might have been the principal nonresonant response.

Leppington has also completed a very recent paper in which he evaluates asymptotic results for large wave number for a panel that is clamped at the edges (Leppington, 1984). The lead term yields an increase of 3-dB radiation efficiency over that for simple supports. This is well known, but additional terms have been determined by Leppington.

Leppington and Levine are jointly participating in research in two additional areas:

1. They are calculating the radiation from vibrating bodies in a mean flow. This is a different approach from that used by Dowling and Ffowcs Williams (1983). They feel that the work of Dowling and Ffowcs Williams is somewhat complicated and are endeavoring to evolve simpler formulations stemming from some work of K. Taylor (1978). Basically, this work involves the use of pointwise Lorenz transforms. It is valid presently only for steady mean flows.

2. They are also commencing work on the basic theory of porous or fibrous materials used for sound absorption. They are particularly interested in the case where the material is near a vibrating plate or panel and where the material itself undergoes vibration.

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*Patrick Lecky
1/12/85*

UK SETS UP SPACE CENTER, GIVES £7M TO EUROPEAN PROJECTS

The UK is planning to set up a British National Space Center to improve the development of space technology and to coordinate space policy more effectively. This move comes at the same time as a government decision to spend £7 million (\$8.1 million) over the next 2 years on feasibility studies for European space projects in the COLUMBUS program.

The center will help manage any contribution the UK makes to COLUMBUS, the space platform that is to be part of the US manned space station. According to *The Times* (London, 30 January 1985), space experts in the UK are eager to use this unmanned platform for experiments in microgravity and for Earth observation missions.

At the European Space Agency's (ESA) Council of Ministers meeting in January, the UK recommended that Europe respond positively to the US invitation to participate in the space station project. Geoffrey Pattie, UK Minister of State for Industry and Information Technology, said, "The British contribution in Europe's COLUMBUS program will be distinctive in that we are aiming to lead on the design of space platforms. This element of the program has been chosen because of its commercial promise and because it is particularly suited to the needs of British users."

Pattie said the UK's new space center is needed because "the responsibility for space has been scattered around government departments, academic institutions, and industry. There is clearly a need for a much sharper focus for Britain's space effort."

For background on the ESA's long-term plans in space science and on the January Council of Ministers meeting, see ESN 39-4:169-173 (1985).

*Larry E. Chaffer
1/17/85*

SPECIAL ISSUE ON SCHOOL PSYCHOLOGY

The *International Review of Applied Psychology* has devoted its first number of 1985 (Vol 34, No. 1, January 1985) to school psychology, with particular

emphasis on the French-speaking world. Contributions include: a review of the origins and early days of scientific psychology in education theory; the psychologist's influence on teachers and the teaching process; measuring classroom climate; effects on performance of teacher evaluative comments in guided discovery learning; attitudes toward mathematics; interactive regulatory processes in small groups working on mathematics games without teachers; interaction in learning groups and the development of measuring skills; assessment of listening skills; hypothesis formation and revision during the process of reading comprehension; the social-psychological impact of school selection and failure; the causes of success and failure in primary schools. Five contributions come from French-speaking Belgium, three from French Switzerland, and one each from France, French Canada, and England.

*Richard E. Snow
1/13/85*

NATO ADVANCED RESEARCH WORKSHOP ON STRESS AND TASK DEMANDS

NATO will sponsor an Advanced Research Workshop on adaptation to stress and task demands, emphasizing new research on the energetical aspects of human information processing. The meeting is scheduled for August 1985. For details, contact Dr. G.R.J. Hockey, Department of Psychology, University of Durham, South Road, Durham DH1 5YN, UK.

*Richard E. Snow
1/13/85*

COGNITIVE PROCESSES IN STUDENT LEARNING

An international conference on cognitive processes in student learning will be held at the University of Lancaster in the UK from 19 through 21 July 1985. The aim is to bring together basic theory and research in cognitive psychology with new research on knowledge and skill acquisition in the academic disciplines of college level study. The conference is sponsored jointly by the Cognitive Psychology Section of the British Psychological Society and the Society for Research into Higher Education. Proposals for papers, symposia,

and workshops are invited. Write to Dr. John Richardson, Department of Psychology, Oxford University, Uxbridge, Middlesex UB8 3PH, UK.

Paul Foman
2/11/85

FIFTH EUROPEAN ANNUAL CONFERENCE ON HUMAN DECISION MAKING AND MANUAL CONTROL

The Fifth European Conference on Human Decision Making and Manual Control will be held from 3 through 5 June 1985 in West Berlin. It is organized this year by the Institute of Automotive Engineering of the Technical University, Berlin, West Germany. The meeting and hotel facilities are at the Conference Center Villa Borsig, Reiherwerder, at the Lake of Tegeler in North Berlin. Topics will include: man-machine interaction, man-computer interaction, manual control, supervisory control in decision-making and fault management, human performance, and modeling. There will be special emphasis on: industrial process control; hardware and software human factors, vehicle control, manipulators, and rehabilitation. For information and registration, contact Institut für Fahrzeugtechnik, Technische Universität Berlin, Sekr. K1, Strasse des 17 Juni 135, D-1000 Berlin 12, Federal Republic of Germany.

Paul Foman
2/11/85

BRITISH PSYCHOLOGY SURVEY

The British Psychological Society has taken over the continuing publication of this series. The current volume is *British Psychology 4*. Each chapter of each volume aims to describe for the general psychological community the current state of research and theory in a particular domain of inquiry. The volumes are particularly useful for keeping up to date with British psychology.

Paul Foman
2/11/85

A NEW JOURNAL FOR SUBMICRON SCIENCE

A bimonthly journal entitled *Journal of Submicron Science* has been just launched by Academic Press (221 Old Orchard Road, Orlando, Florida, 32837; Europe: 24-25 Oval Road, London NW1 7DX).

There are two fascinating phenomena of change in scale that came together in the birth of this periodical. For one thing, microminiaturizing has dominated the scene for many years now, not only in information and communication technology, but also in rather basic areas of physico-chemical research. On the other hand, a less joyous proliferation in the number of very strongly specialized research journals can be also observed. In any case, we have now a strongly focused journal that concentrates on submicron structures.

By the very nature of the properties, basic theory, manufacturing processes, and applications of such structures, the journal is interdisciplinary and covers areas of physics, chemistry, materials science, electrical and optical engineering, computer elements, sensors, circuits, devices--all based on the peculiar world of submicron-dimension systems. These are particularly important in semiconductors. To cite just one example, superlattices--that is, semiconductor crystalline materials where an artificial extra periodicity is imposed--exhibit remarkable quantum properties that may revolutionize the technology for the fifth generation parallel computing machines.

However, the new journal will cover not only semiconductors but also materials which have metallic, insulating, and superconducting properties. It will publish articles on the electronic and mechanical properties of synthetic structures as well as on the transport and dynamical properties of heterogeneous solids. Articles on microstructures dealing with surface physics, crystal growth, interface phenomena, devices, and all applications are encouraged.

The subscription price is £75 or \$132, and sample copies can be requested from the Journal Marketing Department of Academic Press.

Paul Foman
2/11/85

ONRL COSPONSORED CONFERENCES

ONR, London, can nominate two registration-free participants in the conferences it supports. Readers who are interested in attending a conference should write to the Scientific Director, ONRL, Box 39, FPO New York 09510.

The Role of DNA in Brain Activity, Naples, Italy, 27-29 May 1985.

Growth Factors in the Nervous System, Oxford, UK, 3-5 June 1985.

First European Conference for Research on Learning and Instruction, Leuven, Belgium, 10-13 June 1985.

Seventh International Symposium on the Mathematical Theory of Networks and Systems, Stockholm, Sweden, 10-14 June 1985.

Influence of Electric and Electromagnetic Fields on Biological Structures

Symposium, Bologna, Italy, 24-29 June 1985.

Inaugural Meeting of the European Society for Cognitive Psychology, Nijmegen, The Netherlands, 9-12 September 1985.

Technological Application of Bilayers, Vesicles, and Langmuir-Blodgett Films, Denerja, Spain, 25-29 November 1985.

EUROPEAN VISITORS TO THE US SPONSORED BY ONR, LONDON

<u>Visitor</u>	<u>Areas of Interest</u>	<u>Organizations to be Visited</u>	<u>Want Information? Contact at ONRL</u>
Dr. Philip A. Hayes Environmental Sciences Div. Royal Air Force Inst. of Aviation Medicine Farnborough, Hants GU14 6SZ	Thermal Physiology	Hyperbaric Medicine Program Center Naval Medical Center, Bethesda (June 1985) Univ. of Texas at Austin (June 1985)	CDP A. Manalaysay
Professor Kenneth Easterling University of Luleå S-951 87 Luleå Sweden	Metallurgy/Ceramics	ONRHQ (18 July 1985) DTNSRDC (19 July 1985)	Kenneth Challenger
CPT Arnold Böhner Rekruterings en Selectiecentrum Sector Psychologisch Onderzoek Kazerne Klein Kasteeltje 9de Linielaan 1000 Brussels Belgium	Military Personnel Psychology	NAVPERSRANDCEN Univ. of Minn. ONRHQ (Aug.-Oct. 85)	James W. Daniel

SCIENCE NEWSBRIEFS FOR FEBRUARY AND MARCH

The following issues of *Science Newsbrief* were published by the ONR, London, Scientific Liaison Division during February and March. *Science Newsbrief* provides concise accounts of scientific developments or science policy in Europe and the Middle East. Please request copies, by number, from ONR, London.

<u>Science Newsbrief Number</u>	<u>Title</u>
3-7	International Conference and Exhibition on Advances in Command, Control, and Communication Systems, by Paul Roman.
3-8	Physical Chemistry Meeting Set for Strasbourg, by David Venezky.
3-9	Meeting on Fast Reactions in Solution To Be Held in UK, by David Venezky.
3-10	AMPTE Space Mission Has Setbacks, Successes, by Norman F. Ness.
3-11	Scottish Firm Set Up To Develop New Controlled-Release Systems Based on Hydrogels, by Thomas C. Rozzell.
3-12	Ocean/Atmospheric Research Group Formed in UK, by LCDR Rich Kelley.

FEBRUARY MAS BULLETINS

The following *Military Applications Germany (MAS) Bulletins* were published by the ONR, London, Military Applications Division during February. The *MAS Bulletin* is an account of naval developments in European research, development, test, and evaluation. Its distribution is limited to offices with the US Department of Defense. DoD organizations should request copies of the *Bulletins*, by number, from ONR, London.

<u>MASB Number</u>	<u>Title</u>
12-85	Outboard Hydraulic Drive Combination Rudder-Propeller
13-85	European Aerospace Update
14-85	Dornier Advanced Technology for Next-Generation Stand-Off Missile Systems
15-85	Northrop/Dornier Next Generation Fighter Aircraft Technology
16-85	Self-Foaming Fire Agent
17-85	MM-Imaging Radiometry Developments at DFVLR in West Germany
18-85	Edinburgh Instruments Ltd. Infrared Lasers and Laser Accessories
19-85	Experimental SAR Developments at DFVLR in West Germany
20-85	Swedish Meteorological and Hydrological Institute (SMHI)
21-85	New Polar Research Organization in Sweden
22-85	Ocean Surface Current Rada (OSCR)
23-85	Meteorological Systems From a Swedish Company
24-85	Remotely Piloted Vehicles (RPV) Conference in Bristol, UK, 9-11 September 1985

ONRL REPORTS

To request reports, check the boxes on the self-addressed mailer and return it to ONR, London.

- C-1-85 *Third European Congress on Biotechnology*, by Claire E. Zomzely-Neurath. The Third European Congress on Biotechnology was held in Munich, West Germany, from 10 through 14 September 1984. This report examines trends in biotechnology suggested by the congress as well as the congress papers on thermophilic microorganisms, biosurfactants, immobilized cells and enzymes, applied genetics, food and feed bioprocesses, and fine chemicals and pharmaceuticals--bioprocesses and down-stream processing.
- C-2-85 *Sixth International Conference on Fracture*, by Kenneth D. Challenger. The Sixth International Conference on Fracture was held in New Delhi, India, in December 1984. This report discusses work on the mechanisms of fracture, mechanics, fracture of nonmetallic materials, composites, and dynamic fracture. US and UK scientists and engineers are setting the pace for development in the field of fracture, but there are major research programs in Japan, Australia, France, West Germany, India, and China. The use of fracture mechanics for safety analysis and residual life estimation is widespread, but its use in design is still quite limited.

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